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# THE NATURAL HISTORY

OF

# ERISTALIS TENAX

OR

# THE DRONE-FLY.

With Illustrations.

BY

GEORGE BOWDLER BUCKTON, F.R.S.

London
MACMILLAN & CO.
AND NEW YORK
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# PREFACE.

Although this history of *Eristalis* does not aspire to the dignity of a monograph of the genus to which it belongs, it is offered as a contribution towards the writing of such a monograph.

The science of natural things expands, and the problems involved become more and more intricate as we seek the reason of things. Methods conducted on close attention to the individual parts of a biological system must give valuable aid towards understanding the whole, or portions of the same; but master-minds alone can successfully generalize on the accumulating materials they find at their disposal.

As this essay does not treat on the important branches of Embryology and Histology, it may disappoint the adept; yet the author has not treated his subject in what may be called the popular style, which, though it may raise wonder and offer some romance connected with insect-life, is not often successful in giving the knowledge only to be obtained by close study, and by a conscientious application to details which are necessarily often dry.

The author will have fulfilled his task if he has elicited the interest of the general reader, and if in any way he may help some of our rising entomologists, who, possessing good microscopes, wish to take up original research with reference to the Physiology of Diptera, concerning whose history there is much good work yet to be done.

As affording convenience in reference, the materials of this essay are ranged under specific headings; but as Physiology cannot be discussed wholly apart from Morphology, indulgence is asked from the reader where unavoidable repetition may occur in the text.

The addition of a short table of contents and an index, will help the student in finding his way to those pages which may more particularly interest him.

The author here wishes to express his obligations to his friend Prof. Rupert Jones for his kind assistance in passing these sheets through the press, and also for his valuable suggestions as to the distribution of *Eristalis* in geological times.

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Disjointed notes on *Eristalis tenax* are to be found scattered through many memoirs; but hitherto no connected history of this insect has appeared. Early interesting notices of the larva are to be found in the works of Swammerdam, Réaumur, and DeGeer. Later and more modern observations may well be consulted, such as those of George Newport, O. Westwood, B. T. Lowne, and Jules Künckel d'Herculais, all of whom have cited this insect for examples in support of many interesting points connected with general insect anatomy.

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N.B.—Whilst these sheets are passing through the press, Prof. Miall is publishing his admirable book on the 'Natural History of Aquatic Insects' (1895). The reader's attention may be called to the interesting chapter he gives on *Eristalis*, pp. 198–218 of the above work.

# THE GENUS ERISTALIS.

## INTRODUCTION.

PRIMITIVE man must soon have felt the necessity of mentally grouping the objects which appealed to his senses, and of noticing, more or less definitely, those animals which tended to his well-being or the contrary. One of the earliest written records pictures to us animals brought before early man to see what he would call them, and "whatsoever he called every living creature, that was the name thereof." Doubtless this first attempt at nomenclature was based on a sense of their similarities and dissimilarities.

Early thinkers and lovers of systematic order, from the days of Aristotle, have essayed to form some consistent digest of the vast biological materials before them, comprising the thousand on thousand species of the animal and vegetable world. A more critical age soon recognized that the characters most obvious to the eye, such as mere form and colour, if alone considered, only led to mistakes, and that such a grouping could not be considered, in any sense, a natural or perfect system.

The splendid labours of Hunter, Cuvier, Owen, Milne Edwards, Huxley, and others, directed to Comparative Anatomy, showed some of the lines on which biological classification should be founded; and when to these were added the recent discoveries in Physiology, Morphology, and Embryology, students felt that they were resting on surer ground than it was possible for our forefathers to have attained.

Nevertheless, Huxley reminds us that "the last appeal to Embryology for the morphology of the skeleton is not final. We have still to look to Palæontology for confirmation or contradiction of our deductions from the facts of Embryology." Again: "Biological evolution is based on the history of life on our planet, as witnessed by the facts of Palæontology; however they may be interpreted."

As regards Insects, the morphological variations are so great that a study of their life-history is imperative, for no true system of classification can be complete without it. Even the same species of insect may differ so widely from others of the same genus at various stages of its life, its internal and external organs may undergo such profound modifications necessitated by its surroundings, that, as George Newport remarks, "it becomes one of the most interesting investigations of the physiologist to ascertain the manner in which these changes are effected."

If the already well-debated problem of the development of higher forms out of lower, or the converse—if persistent forms can be originated through degradation—is to be solved, better results may be expected from a broad harmonious taxonomy than from a laborious comparison of details of external shape and colour, or from a compilation of names ranged under genera of doubtful value. But descriptive lists have their value; for without their assistance it would be impossible for one observer to convey to another clear ideas of the identical forms to which he wishes to call attention.

Of the Invertebrata, perhaps Insects show the highest marks of specialization. Through their remarkable powers of variation and adaptation to circumstances, they can sustain themselves in air or water, in living animal and vegetable tissues, and even in rotting matter, the condition of which often raises surprise that any highly-organized animal could thrive in it. But in a week's time, or less, the life-habits of an insect may entirely change. Thus the foul-feeding grub of *Eristalis* may become the gay and active fly, delighting in sunshine, whose only food is the honey and the pollen of flowers.

Although the Diptera cannot vie with the Lepidoptera in their gorgeous colouring, many two-winged flies are brilliant insects, and present numerous points of interest in their economy. On the utilitarian side many Diptera prove themselves to be very effective scavengers. They remove vast masses of decaying matter, which otherwise would breed disease amongst us. It has been calculated that from the eggs of a single blowfly, *Calliphora erythrocephala*, the hatched maggots, under favourable circumstances, can consume the carcase of a horse as expeditiously as can a lion. Many Diptera assist also in the fertilization of flowers.

On the economical side, for evil, this important order of insects may be respected, but feared from the amount of misery they can cause to both man and beast. Whilst they furnish for us neither honey nor wax, and, unlike the locust and *Cicada*, they do not afford the epicure any juicy dish, they are pests to the agriculturist and to the bee-keeper. Blood-suckers, flesh-burrowers, skin-irritators, disease-propagators, they plague the living, though as sarcophagi they consume the dead.

The perpetual snows of Greenland and the scorching heats of Africa are all one to the mosquito tribe, whose blood-thirsty habits against man must pass by inheritance, since in Arctic regions not one individual in a million can ever have met with the human race. The bare mention of the ox-bot, the gadfly, the Hessian fly, the flea, the South American *Chigoe*, and the African *Tetse*, is sufficient to show that, though these foes may be very small, they often are very wicked tormentors.

Prof. Westwood suggested that the Egyptian plague of flies were Diptera, bred from the Nile-mud; and that the fact of the land of Goshen being largely composed of sand might explain how that tract was exempt from this plague.

The family of Syrphidæ may be regarded as beneficial insects. Many species are aphidivorous, and thus they protect the farmer and horticulturist. *Helophilus* and *Stratiomys*, and some other dipterous genera, are in habit like *Eristalis*, and they also, as consumers of effete matter, may be thought to be beneficial. But the handsome *Volucellæ*, though they destroy many wasps in the larval stage, are very destructive to the honey-bee, upon the live brood of which they feed.

Several early entomologists have cursorily noted the occurrence of the *Eristalis* fly, and some few observers have given rough woodcuts of its maggot or larva. Though this be so, no complete description of the habits and anatomy of the species may be said, up to the present time, to have appeared.

The first description of the insect, which is at all circumstantial, occurs in Réaumur's 'Histoire des Insectes,' in which he describes the larva under the name of "le vers à queue de rat," and he remarks that the worm swims with its head downwards, and that the tail is raised to the surface of the water for the purpose of respiration.

Our English physician, Dr. Moufet, also in 1634 alluded to the larva; and curiously in connection with it he noted and apparently believed in the ancient Greek and Latin tales, that "certain bees may be bred from the carcases of dead beasts."

Baron von Osten-Sacken has quite recently gathered together the chief of these curious myths and stories. He connects them with the fact that *Eristalis* in the adult form is exceedingly like a drone-bee. This fanciful idea as to the breeding of bees will be alluded to in a later portion of this essay.

It is probable that some of the insects stamped as "stingless bees" on ancient Greek coins, on closer examination will prove to be representations of *Eristalis* or the *Bugonia* of the Greeks.

The larva of this fly when floating on water shows a certain play of iridescent colours, compounded of pale bluish and rosy tints. This circumstance probably suggested to Linnæus the generic name which he gave the creature; for Pliny speaks of a white gem, *Eristalis*, "which appears to blush at inclinations of the light"—"gemmæ candidæ quæ ad inclinationes rubescere videtur." The name of the closely-allied genus *Helophilus*, or marsh-lover,* doubtless refers to its common habitat in swampy places.

# I. CLASSIFICATION.

## DIPTERA.

The insect-order Diptera is strictly natural; but it comprises, as has been above shown, forms capable of great adaptability; and accordingly the thoughts of many systematists have been exercised so as to ensure to them a more or less truthful position in the section to which they belong. A great deal in classification must depend on the values assigned to such details as the wing-veining, the characters of the mouth and of the antennæ, and the modes the insects adopt in procuring their food, &c.

Latreille, in his system, laid much stress on the construction of the trophi or mouth apparatus (cibarian system); whilst Macquart took the details of the antennæ chiefly for his guide. Prof. Westwood partly combined the two schemes, and he grouped the order under two sections and five stirpes. He † attached much significance to the conditions of complete or incomplete metamorphosis of insects (coarctate and obtectate pupæ). In his system we have the families Syrphidæ, Conopidæ, Muscidæ, and Astridæ, closely grouped together, under the stirpes *Anthericera*, Latr.; whilst the Stratiomidæ and Tipulidæ are far removed, though in economy they have so much in common.

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* From *helos*, a marsh.

† Westwood, 'Mod. Class. of Insects,' vol. i. p. 505.

Mr. Francis Walker* ranges the order differently, under three sections,—Suctoridea, Proboscidea, and Eproboscidea. The Proboscidea, which include the Syrphidæ, again he divides into Nemocera, Brachycera, and Hypocera. Brachycera comprises nineteen families, under which systems Syrphidæ range the twelfth and Muscidæ the sixteenth. Once more, Syrphidæ are divided into thirty-one genera, of which *Eristalis* is the fifth and *Volucella* the thirteenth in the order of their affinities.

The chief characters here are taken from the antennæ, the form of the mouth-part, and the wing-veining. The life-history is not much considered, nor the aërial and aquatic habits of the larvæ.

Briefly, the position of *Eristalis* (according to Walker) is shown by the following table, which, though incomplete, will sufficiently serve the purposes of this essay.

## SYRPHIDÆ.

### SYNOPSIS RELATING TO THE POSITION OF BRITISH SPECIES.

| ORDER | SECTION | TRIBE | FAMILY | GENUS |
|---|---|---|---|---|
| DIPTERA | I. Suctoridea | . . . . . . | 1 Pulicidæ | |
| | II. Proboscidea | 1 Nemocera | 10 Tipulidæ | |
| | | 2 Bachycera | 12 Stratiomidæ | |
| | | | 16 Asilidæ | |
| | | | 25 Syrphidæ...... | *Eristalis*<br>*Helophilus*<br>*Volucella* |
| | | | 27 Muscidæ | |
| | | | 28 Astridæ | |
| | | 3 Hypocera | 29 Phoridæ | |
| | | | 30 Hippoboscidæ | |
| | III. Eproboscidea | . . . . . . | 34 Nycteribidæ | |

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* F. Walker, 'Insecta Britannica,' vol. i. pp. 242–247; plate ix., with fig. of head and wing only.

## ORDER DIPTERA, *Latreille.*

Mouth fitted for suction and provided with palpi. Proboscis usually fitted with lancets. Ocelli three. Wings two, never plicated. Halteres or poisers two, and placed under or behind the wings. Tarsi pentamerous. The labium mostly acts like a pump; but in predacious species it operates like a piercer. The setæ or lancets may be as many as five in number. Pupation sometimes incomplete or is complete. The ocelli rarely amount to only two. Antennæ vary in articulation from one to ten or more. Tarsi five-jointed, with two pulvilli and claws.

The late Mr. Francis Walker placed *Eristalis* fifth on his list, between *Eumerus*, the larva of which feeds on bulbous roots, and *Helophilus*, which lives in ponds.

The dipterous insects *Stratiomys*, *Culex*, *Corethra*, and *Chironomus*, are all aquatic at some period of their lives, yet in the above classification they are all far removed from the Syrphidæ. This last family indeed is very erratic in habit; the larvæ of most of the other species are terrestrial, but some are aquatic and some are carnivorous.

There are considerable mental difficulties in grasping the modes and the means through which such changes of life in the individual have come about. Until we have additional evidence it will be unsafe to lay much stress on such secondary characters for the purposes of classification, though they may be very striking.

Such problems become the more accentuated in difficulty when we know that warm-blooded mammalia with true lungs are now ploughing the sea, side by side with fish possessing gills; and again, among insects, that Ephemeræ, with gill-like organs, are living side by side with water-insects, which breathe air exclusively through tracheæ.

The larvæ of Diptera most commonly are footless and maggot-like. Their outer integuments finally harden into a tough puparium or sheath, within which the true pupa or nymph is developed. Nevertheless some larvæ have false feet (pseudopodia), somewhat similar to those seen on the lepidopterous caterpillar.

In many respects the Diptera counterfeit and resemble Hymenoptera. Thus, whilst *Eristalis tenax* counterfeits the honey-bee, *Volucella zonaria* and some other Syrphidæ imitate wasps and hornets.

The imagos of Diptera possess no mandibles, but some larvæ develop crushing teeth at the entrance of the proventricle or crop, which may be supposed to represent them.

## ERISTALIDÆ.

### LIST OF BRITISH SPECIES.

Mr. G. H. Verrall mentions the following insects in his 'List of British Diptera,' published in 1888 :—

*Eristalis sepulchralis*, Linn.
,, *æneus*, Scop.
,, *cryptarum*, Fab.
,, *tenax*, Linn.
,, *intricarius*, Linn.
,, *arbustorum*, Linn.
*Eristalis rupium*, Fab.
,, *pertinax*, Scop.
,, *nemorum*, Linn.
,, *horticola*, Deg.
,, *apiformis*, Fln.
,, *fumipennis*, Steph.

The late Mr. F. Walker has *E. fossorum*, *E. similis*, and *E. floreus*, in addition, which are considered now to be synonyms of other species.

Of these, *Eristalis tenax*, *E. arbustorum*, and *E. floreus* are common in many parts of England; but *E. fumipennis*, *E. cryptarum*, and *E. rupium* are rare.

As this essay is almost entirely confined to a history of *E. tenax* and *E. arbustorum*, a diagnosis of these two species alone will here be necessary.

## DIAGNOSIS.

### GENUS ERISTALIS, *Linn.*

Head large, semiglobose. Eyes ample, and covering much of the frons and the epistoma above the proboscis. Vertex with a hemispherical tubercle, on which the three ocelli are conspicuous; epistoma shining, and densely clothed with hair, hollow and notched below to receive the folded haustellum or proboscis. Labrum short, and cleft at the tip. Mentum forms a flexible hinge, and unites with the proboscis at a sharp angle. Palpi cylindrical, and longer than the maxillæ. Antennæ with four joints (Walker says five), rising from under a projecting hood about the middle of the face. First joint very small; the second patelliform and embracing the third, which is the largest; oval, and furnished at the side and near its base with a fine seta. Thorax oval and hairy. Wings with subcubital cell entire to the margin. Axillary lobe distinct. Subcostal and radial veins meeting before they reach the margin. Alulæ formed of a double scale, which is fringed. Halteres small, and placed below the alulæ. Abdomen obconical. Tarsi with five joints; the first the longest; the last ending with two claws, two pulvilli, and two setæ.

ERISTALIS TENAX, *Réaum.; Fab.; Gm.; Meig.*

*Eristalis porcina*, DeGeer.
,, *arbustorum*, Linn.
,, *apiformis*, Gf.
,, *campestris*, Meig.
,, *hortorum*, Meig.

## THE IMAGO.

Colour piceous, and covered with tawny hair. Epistoma black, oval, shining, with obscure transverse furrows, and with a small tubercle, below which a deep notch marks the peristoma. This is hollow, and covers the proboscis. The epistoma is surrounded by a mat of glistening tawny hair, which becomes blacker as it approaches the vertex. Proboscis when folded is not visible from above. Eyes large, thickly reticulated, and violet-brown in colour. Abdomen of female with four rings, each fringed at its lower borders. The second somite much the largest. The last somite of the female ends with two papillæ or valves and a long, jointed, retractile ovipositor. Femora hirsute; hind tibiæ bent, yellow above and brown below. Wings hyaline, rather dusky, and in some specimens stained with brown just below the costal edge.

F. Walker notes two varieties of *Eristalis tenax*, viz.:—

α. Wings clouded with brown beneath the fore border.

β. Abdomen with a narrow interrupted tawny stripe on the second segment; spots near the base very large and distinct.

## THE LARVA.

From the exclusion from the egg up to the time of pupation this insect is aquatic, and accordingly its respiratory apparatus is modified from that seen in the generality of Syrphidæ.

Like many other aquatic early forms, it somewhat resembles a tadpole. The larva consists of a soft slug-like body, ending with a long retractile tube, which in fact represents two extended spiracles. Body soft, gelatinous, eyeless, and without visible division into rings or somites. There is no distinct head, but the anterior part is furnished with two rounded tuberculatory swellings, studded with numerous spines, some of which are large, recurved, flat, and sickle-shaped. These tubercles act as rasping organs, by which the food is comminuted before it passes into the œsophagus. The tubercles are connected with a strong chitinous notched tooth, which can be withdrawn into the cavity of the body, together with the tubercles, and at the will of the animal. A tridentate plate at the entrance of the pharynx leads into a kind of gizzard, and by its masticatory action the passing nutritive matter is rasped into a pulp. Two cornua, which do not seem to be perforated, rise from the region of the head, and project slightly above the integument. They can also be entirely retracted within the integument. The body of the maggot is cylindrical. On the ventral surface seven pairs of dusky spots are seen, each of which under the microscope is found to consist of two incomplete circles of minute hooks, like those of the false feet of a caterpillar. These are the pseudopodia. They enable the larva, when out of water, to creep with some celerity over mud and over moist surfaces.

The posterior end of the larva terminates in a long tube composed of three joints of different calibre, and capable of sliding one within the other, like the adjustable tubes of a telescope. Before the insertion of this tracheal organ the anus appears; it consists of a blunt tubercle surrounded by from eleven to fourteen leaf-like flaps. In the centre of this tubercle an aperture occurs in the form of a slit, which is the termination of the rectum.

This complex respiratory appendage is capable of considerable elongation, so much so that a larva with a total length of two centimetres can protrude its tube as much as eleven, making the entire length of the creature thirteen centimetres, or four inches nearly. The organ, however, is not often extended to this great length. The caudal tube (*queue de rat*) ends in a cup- or funnel-shaped opening, garnished with either five or six strong bristles or setæ opening out in a circle.

These seem to be lubricated with some oily fluid, which repels water. Thus when the larva thrusts its long compound spiracle to the surface a funnel or depression is distinctly made, and through this the air enters the respiratory tubes.

The general colour of the larva of *Eristalis tenax* is a bluish white suffused with pink. It is semitransparent. Down the dorsum a long dark track appears, which exhibits the dark fluids of the larva moving rhythmically and in pulsations from the tail-end to the head. This dark space is enclosed by two long yellowish bundles of fat-vessels, which largely increase in bulk as the larva approaches the time of its metamorphosis. On account of the abundance of this adipose tissue it is very difficult successfully to unravel the folding of the alimentary and other viscera situated below them.

Two pretty conspicuous silver-white lines also run the whole length of the larva. These are the great tracheal trunks; the reservoirs or air-sacs which store the air taken in at the caudal spiracles to be distributed all over the internal viscera. They are capable of considerable distention, and also of contraction, by means of their muscular coats. Thus the insect can alter its specific gravity in the water; it can sink, rise, or remain in suspension at will. If the larva be dropped into hot water, the air contained in these air-sacs may be recognised by the expulsion of a stream of minute bubbles issuing from the end of the respiratory tube.

Though never active in their movements, the larvæ, while floating, show a continual constrictive and undulatory motion, which proceeds from the tail to the head, and gives the appearance of creeping like a caterpillar. During this action the front tubercles are alternately protruded and retracted, and water is taken in by gulps and forced backwards to the pharynx. Though a support is gladly used if it be available, the grub can sink or swim at pleasure, through the action of these great air-trunks. Some of the rough figures given by our older naturalists represent these larvæ hanging in parallel rows, all with their heads downwards. They usually form knots of eight or more, each giving mutual support.

The back of the larva shows here and there disjointed portions of small cylindrical vessels filled with a blood-red fluid. The colour of the liquid, which does not contain corpuscles, is similar to that which fills the body of the larva of the somewhat common gnat, *Chironomus plumosus*, familiarly known as the blood-worm. The significance of these vessels I have been unable to discover, as they appear to be neither salivary nor Malpighian in function.

The details of the internal anatomy of *Eristalis tenax* and the accompanying illustrative figures, will be treated at length elsewhere.

## The Puparium.

The intermediate stages between the larva and the adult insect differ from those to be noted in Lepidoptera. Instead of the outer integuments of the larva being cast off just before pupation, as in the caterpillar, it hardens into a tough and horny case, within which the nymph forms its own special membranous envelope. This subsequently separates itself from the shell above noted. The last moult of the larva in this manner furnishes a kind of cocoon and a protection to the pupa during the time necessary to complete the final metamorphosis, resulting in the production of legs, proboscis, wings, and antennæ, none of which are to be found in the original larva of *Eristalis*.

The shape of the puparium is a long oval. The anterior part is fitted near the region of the head with two short recurved cornua; and near the region of the thorax with two longer similar appendages.

The integument is hard and thrown into numerous transverse rugæ or furrows, continued to an indistinct lateral carina. The under side is smoother, but is marked by obscure protuberances—the vestiges of the eight pseudopodia to be found in *Eristalis arbustorum.* (There are only seven false feet to be seen in the puparium of *E. tenax.*)

The anal tubercle also is duly represented in the puparium. Similarly eight distinct depressions mark out the same number of stomata. Before the skin of the larva hardens into this chitinous case, the joints of the long tracheal tube are partially retracted, and the rest of the organ is twisted round the body and becomes rigid. On the anterior part of the puparium certain sutures show the direction in which the operculum or lid which covers the cephalic part splits and becomes detached. Some authors say this fracture of the case is effected by the forcible expansion of air or of fluid from the anterior parts of the imago within. In *Volucella* the operculum is connected with the body by a kind of hinge, but in *Eristalis* the shield-like plate becomes quite detached, and it falls away.

The colour of the living puparium is muddy brown, without any gloss. If the animal be dropped into water it floats with the tips of the cornua and the branchial tube touching the surface. As will be shown in the remarks on the internal anatomy, these cornua have become the true respiratory organs of the puparium, just as we see them developed in the head of the pupal gnat, *Culex pipiens.* The puparium of *Eristalis* thus would not be suffocated if subjected to an accidental flood of water; notwithstanding that its abdominal stomata are being elaborated at the same time for the use of the future fly. No external motion of the puparium of any kind can be detected. The future insect is bound fast in its chitinous walls, which are so hard that they rattle if struck by a hard substance like a pencil. The puparium is buried, but not deeply, in mud, and this is doubtless a protection against drought.

M. Künckel d'Herculais, objecting to the term pseudochrysalis, proposes the word hypnothèque, meaning somnolency. The word puparium is commonly accepted, and therefore I retain it.

The head, wings, and the lower part of the anal ring of *Eristalis arbustorum* are greyer than the rest of the body. When the operculum separates it carries with it the two shorter cornua, but the longer cornua attached to the thoracic ring are retained on the puparium. If sufficient care be taken, the nymph may be separated from the chitinous covering. Spots thus may be easily recognised, with indications of the pigment of the eyes. The rudiments of legs and of the wings also can be made out under the investing membrane which forms the clothing of the pupa.

## ERISTALIS ARBUSTORUM, *Gm.; Schr.; Pz.; Mg.; Mq.; Zett.; Walker;* and others.

### THE IMAGO.

Head globose. Eyes large, dark brown, and approximate at the vertex. Epistoma large and densely clothed with silvery hair; from the upper part the black antennæ spring. Thorax warm brown, and clothed with fulvous hair. Scutellum large and shining. Abdomen transparent, broadest at the base, and gradually tapering towards the apex. Colour fulvous-yellow. First ring narrow; second very broad, with a dark piceous, dorsal, and somewhat dentated mark, which is continued and widens as it passes down the third segment; fourth ring all dark brown. Each segment has a narrowly fulvous-yellow edge. The whole abdomen is finely pilose. Legs black; middle tibiæ and tarsi yellow at the bases. Wings colour-less or nearly so. Alulæ double, conspicuous, and greyish white.

The late Francis Walker names three varieties, chiefly differing in the amount of yellow integument uncovered by the brown stripe.

My engraving (Plate II., fig. 3) is coloured from an Irish example. The species is common and widely distributed.

### THE LARVA.

The larvæ are smaller than those of *E. tenax*. The pseudopodia are more developed, and they become more evident as the insect approaches pupation.

A coloured drawing of a young specimen will be found Plate II., fig. 2.

### THE PUPARIUM.

The greater part of what has been given with reference to this stage of *E. tenax* will apply also to *E. arbustorum*.

Length of larva, 0·50 inch, or 13·0 millimetres.

Length of imago, 0·85 × 0·50 inch, or 22·00 × 13·00 millimetres.

## II. LIFE-HISTORY OF ERISTALIS.

My special attention to *Eristalis* was called by the plentiful occurrence of the slug-like larvæ during the summers of 1893 and 1894. These were seen floating in knots of from seven to nine individuals on the surfaces of some ponds at Haslemere frequented by cattle.

The marked abundance of some species of insect in some years, contrasted with their rarity in other years, is a circumstance not always easy to account for. Much may be ascribed to a favourable temperature at the season of the exclusion of the larvæ from the eggs, and much to the more or less abundance of food at this critical time of their lives. Again, the fact of a scanty or a heavy rainfall may have some bearing on the subject; but perhaps more often the absence of an insect's natural parasites may lead to such a multiplication of a destructive pest as can mar the labours of the agriculturist or gardener over large districts.

Such explanations, however, only partially meet the question why the little chaffer, *Phyllopertha horticola*, should, during the summers of 1893 and 1894, have infested the turf of the Surrey hills in such quantity that the surfaces of the meadows could be rolled into dry masses as if a turfing-iron had been employed. Later in the year, the flying beetles were gathered, at Haslemere, into bushel-baskets to be burnt; yet this treatment hardly diminished their numbers in the following year. In 1895, though much less prevalent, these beetles might be shaken, six or eight at a time, from the centre of a single rose, whilst engaged in devouring the pollen.

The hot summer of 1893 reduced the areas of many ponds to small dimensions, and this caused the teeming life of their muddy bottoms to congregate into small pools. Thus many living insects became open to easy investigation, and notably those of *Eristalis tenax* and *E. arbustorum.*

Some preliminary circumstances connected with the occurrence of the larvæ in the above-mentioned ponds may be noted.

Many knots, containing from six to eight rat-tailed larvæ, were found to be closely entangled with cylindrical masses of buoyant transparent mucilage. The same observation was made in certain tubs containing diluted manure water; in which almost every *Eristalis* larva had attached itself to a mass of floating jelly measuring three-quarters of an inch in length.

Another peculiarity consisted in the fact that many *Eristalis* larvæ had tied their so-called tails into regular knots, ostensibly for the purpose of temporarily shortening them.

About a dozen of these larvæ, with their gelatinous attachments, were placed in jars for observation. A lens showed that the mucilage was studded with a hundred or more dark ova disposed in a spiral line on the surface from one end to the other. This association of *Eristalis* with masses of mucilaginous material was quite common from early June to late October in 1893.

The interesting and unexpected facts made known by Prof. N. Wagner, of St. Petersburg, *viz.*, that certain aquatic Diptera possess the faculty of producing larvæ whilst they themselves are yet in the larval condition, came to recollection. Such an unusual mode of reproduction has been since confirmed by Professors Pagenstrecker, Meinert, and others. The phenomenon is well shown in the dipterous insects *Olygarus paradoxus* and *Miaster metraloas.*

It seemed to be desirable to learn whether then there was any biological relation between the ova above noted and *Eristalis*, The mucilaginous cylinders are so glassy-bright that they would be invisible in clear water except from the ova embedded on the surface. On October 14th the ova had burst their outer shells, and each produced a minute larva, singly encysted in a particle of water, thus enabling each insect to writhe and turn itself at will. The cleft shells could easily be seen placed by the side of each disclosed little worm.

On October 16th the larvæ escaped into the free water, which then appeared to be alive with them, each larva rapidly performing the figure-of-eight movement, so commonly seen in *Culex*, *Pipunculus*, and other genera of gnats.

These larvæ developed into bodies with well-defined heads, eyes, and mandibular parts. Each insect had a distinct thorax and abdomen formed of two rings. Two supporting tubes projected from the tail-end, each furnished with a crown of narrow hooks, or rather setæ. A short fringed tube also occurred at the base of the thorax.

In April of the following year many more of these gelatinous masses were found in the liquid manure tubs. Each mass was here suspended by a fine thread four or five inches long, silky, and glossy. The threads at their upper ends were attached to either small pieces of fibre or particles of wood—in fact anything which could act as a buoy to float them at or just below the surface. Fracture of the silken fibre caused the precipitation of the ova with the mucilage to the bottom of the tub.

I bred several of the imagos from these larvæ in confinement, but their wing-veinings were too indistinct to allow me with certainty to settle the species of gnat to which they should be referred. Several gnat larvæ are known to be able to suspend themselves in water at will.

It thus became evident that the larvæ of *Eristalis* only used these gelatinous masses as buoys to facilitate their own respiration without muscular effort. The ova had nothing to do with abnormal larval-reproduction as in *Oligarus* and *Miaster*.

The larvæ of *Eristalis tenax* do not often thrust themselves into general public notice. Nevertheless they caught the observation of Réaumur and his pupil Fabricius more than two hundred years ago. De Geer roughly figured the larvæ, and so did our old physician and naturalist Dr. Moufet.

Amongst the older systematists of the Diptera we may mention Linnæus, Macquart, Meigen, Germar, St. Fargeau, and Serville. In later times we have the competent names of Burmeister, Blanchard, Westwood, and Francis Walker, all of whom have incidentally remarked on the aquatic life of *Eristalis*.

Quite recently Baron von Osten-Sacken, of Heidelberg, the accomplished dipterist, has published interesting memoirs on the distribution of these insects, and the myths connected therewith. I may note also that M. Jules Künckel d'Herculais has produced a fine French monograph on *Volucella*, which, though a genus having no species with aquatic habits, is closely allied to *Eristalis* in its morphology, and supplies much that is suggestive.

The larvæ of Diptera, as a general rule, neither show true heads nor feet. The latter organs would be almost useless in the early stages of *Eristalis*, and accordingly they show but little development until the necessity arises for the larva to quit the water for dry ground and prepare for its pupation, when the pseudopodia, or false feet, become more perceptible.

In *Volucella* the indistinct pseudopodia become more prominent as the age of the maggot increases, and the recurved hooks on the belly increase in number and size as the insect approaches its final metamorphosis.

Although the larva of *Eristalis* is dependent on water for its sustenance and growth, it has the power of progression on land, and can crawl with some rapidity through the use of the above-mentioned false feet. See Plate III., figs. 6 and 10.

The so-called tail, however, is used by the insect as an instrument thrusting from behind, and urging forward the head during the penetration of the grub into wet mud. This organ is the last part of the animal which appears above ground.

There are eight pairs of false feet in *E. tenax*, and seven pairs in *E. arbustorum.* They occur on what appear to be the 4th, 5th, 6th, 7th, 8th, 9th, and 10th body-rings, but the segmentation of the larva is very indistinct.

The larva, living in the midst of its abundant food, elaborates an immense amount of fat, or tissue stored with clear oil, which is consumed by the nymph during pupation. In this quiescent stage the large masses of muscular fibre are formed to work the powerful wings of the adult as soon as it emerges.

The larvæ of *Eristalis tenax* have neither eyes, antennæ, nor external mouth-parts. They appear indeed to be cognizant of little more than the single sense of touch, and this is mostly confined to the region round the blunt projecting tubercles placed on what may be considered as the head of the maggot. The rounded parts are thickly clothed with minute capitate papillæ, or sensitive palps. Plate III., fig. 2.

Mr. H. C. Vine kindly informs me that the larvæ are sensitive to the light of a lamp, even though it be so shaded as to cut off all rays of direct heat. Light clearly here has some stimulus quite apart from an excitation of the sense of vision.

*E. tenax* can sustain long fasts with impunity. The larvæ will live many days in clear water free from animal or vegetable matter. They will live in brackish water, and even in the briny spent-liquors which remain after the curing of bacon.

A similar tenacity of life may be noted in the imago. This character probably suggested to Linnæus the specific name *tenax*. In illustration he relates that some larvæ had been accidentally introduced through the water into some pulp employed in a paper-mill.

Nevertheless they survived the pressure of the beaters or rollers employed in the manufacture of the paper.

The writer has witnessed the escape of the larva from under a heavy-weighted tumbler; the toughness of the skin giving sufficient rigidity to the muscles to allow the grub to progress and bear the load upon it. *

Similarly, Miss E. A. Ormerod † remarks that "the maggot of *Œstrus bovis* can scarcely be pressed flat between the fingers, from a like hardness of the integument."

This toughness increases with the age of the animal. This quality of the integument is much hastened by the action of diluted caustic potash solution. The skin is insoluble even in strong alkaline solutions, and this character proves the substance to have the nature of chitin.

Great tenacity of life is observable in the adult insect. On one occasion the decapitated fly lived for three days and nights on the stage of a microscope. At another time, in September, whilst deprived of its abdomen, an adult fly buzzed for more than an hour, during which it often folded its legs and protruded its proboscis. The thorax even may be sliced for examination; when still the muscular bundles and the viscera within may be seen to twitch and swell upon the application of an irritant or a needle-point.

The adult will bear with impunity a low temperature of 10° Fahr. at the times of its hybernation. On the first warm days of spring individuals may be seen to crawl out of their hiding-places, and soon to become actively engaged in oviposition.

It is stated by some authors that dipterous larvæ do not undergo ecdysis, or the process of moulting. This may be true of some species, but certainly not of all. The casting of skin of *Eristalis arbustorum* occurs at least once, and the body with its new skin may be seen partially disengaged and enveloped by the old one. Plate III., fig. 10, *x x*.

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* G. Newport found that the muscular power exerted by the dor-beetle (*Geotrupes*) equalled eighty ounces, that is, it can move more than one and a half pounds.

† 'Report on Injurious Insects,' p. vii. 1895. E. A. Ormerod.

M. J. Künckel d'Herculais* says of *Volucella*, that "no anterior stigmatic opening appears in the larva until *after the first moult*, and that, though the moults are difficult to follow, they may be recognized by changes in the respiratory apparatus, and the number of hooks developed on the feet."

Notwithstanding this tenacity to life, like many insects the larvæ are markedly sensitive to changes of weather, and particularly to the electricity of thunderstorms. About twenty larvæ of *E. arbustorum*, which seemed to be fully fed, were placed in a large glass bowl, with water. The result was the death of all from the thunderstorm of the night of August 28th, 1894. The beneficial effects of thunder and lightning may be well recognized by horticulturists in causing destruction to Aphides or "smother-flies," and other insect "blights."

On October 4th two very lively *Eristalis* flies were placed in a box, which could not be examined for three days. Though unfed during this period, they were still very active; but in a transfer to a watch-glass one of the individuals lost its head. No attempt then was made by the insects to fly, but they walked about, without apparent aim, and more or less in circles. A drop of strong alcohol, however, applied to the neck at the point of decapitation, caused almost immediate death of the whole trunk, which proved the close connection of the thoracic and abdominal ganglia of the nervous system.

The loss of wings seems to produce very little inconvenience, for an *Eristalis* fly thus dismembered, when placed on a flower of *Caltha palustris*, immediately plunged its proboscis into the centre, and continued to feed for several minutes.

Larvæ transferred from foul-smelling to clean water do not discharge themselves of their own peculiar ammoniacal odour. It seemed to have entered into their animal economy, and specimens long preserved in weak alcohol still retained their offensive smell.

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* 'Recherches sur l'organisation des Volucelles.' 1875.

As instances of the comparative indifference to the action of very weak corrosive solutions shown by some aquatic larvæ, I may note that for the purpose of staining the transparent parts of *Corethra plumicornis*, several living larvæ were put into water charged with a few drops of a solution of silver nitrate. Although, through the action of light, the liquid soon became so dark that objects could not be seen through it, the larvæ at the end of ten days' time seemed to be as lively as ever.

This solution of "lunar-caustic" appeared rather to act as a tonic; at least their peculiar powers of darting from one side to the other were not impaired. The living tissues of the insect refused to be stained, though dead tissues can thus be stained with great facility. The same larvæ were afterwards placed in a weak ammoniacal solution of carmine, with a similar result of refusal to be stained.

Reverting to the history of pupation of *Eristalis arbustorum*, on the 8th of September eight full-fed larvæ were confined in a pot with earth saturated with water. They soon buried themselves, and each formed a small dome of earth, under which, after the lapse of a week, the investing skins became hard and rigid. Generally their long tracheal tubes were found coiled round the bodies. Plate I., fig. 6. On the eighteenth day the opercula of two had burst open; and shortly afterwards the developed flies liberated themselves. One specimen issued completely formed, but the other was partly crippled, and the wings were only half expanded. Both flies proved to be *Eristalis arbustorum*.

A specimen taken from the same batch of puparia was slit open under water, and the pupa within was dissected out. Black patches of pigment marked out the immature eyes; whilst the mouth-organs and legs, and clear indications of the alimentary tubes, were without much trouble unravelled. A ganglionic mass occurred near the entrance to the proventriculus or crop.

In the puparium the large tracheal vessels could be traced quite to the summits of the cornua; and their connection with these horns was well shown by carefully stretching and tearing the cornua from the rest of the puparium. The elastic trachea was here seen in complete attachment and continuance to the opening. This connection I could never observe in the similar larval organ. Compare Plate I., fig. 8; and III., fig. 3.

The pupa of *Eristalis*, therefore, like that of many other aquatic Diptera, breathes from the thorax instead of from the caudal spiracles; and the elaborate breathing apparatus of the larva is wholly absorbed, and disappears altogether. The upper halves of the respiratory horns are studded with tubercles, the use of which is unknown. Plate I., fig. 8 *a*).

These "cornes stigmatifères" of M. Künckel d'Herculais, though so like antennæ, have nothing to do with those of the imago. In the one case the cornua are thoracic, whilst in the other the antennæ are placed on the frons of the fly.

The integument of the nymph or pupa may be found at one end of the puparium. It consists of a delicate membrane rolled into a ball. By soakage in water it can be partially spread out, as may be seen in my Plate I., fig. 7.

The time spent in pupation varies with the temperature of the season. Sometimes the organs of the imago are very quickly formed; at other times from ten to fourteen days may elapse before the puparium opens.

The males of *Eristalis* are preceded by the females, a fact also noticeable in the case of *Volucella*. This sex is much more commonly seen in some summers than in others. In the early autumn many individuals may be captured of both sexes, with their internal organs developed only in part. Sometimes indeed these immature forms comprise the larger number of the flies on the wing.

As before noticed, the food of *Eristalis tenax* consists of honey and the pollen of flowers. Throughout the summer to the middle of October sometimes three or more flies may be taken on one disc of *Aster cyaneus*, which is a North-American species, and cultivated for ornamental purposes. Many other Syrphidæ also are partial to this flower. Dr. A. Laboulbène, of Anjou, notes that *E. horticola*, De Geer, = *E. flavocinctus*, Fallen, *E. tenax*, and *Helophilus floreus*, Linn., are all common visitors to this and many composite plants.* Notwithstanding the destruction of much pollen, *Eristalis* doubtless largely assists in fertilization of flowers. The chilly evenings of October soon cause the disappearance of the flies; but those females who have failed to deposit their eggs seek out some secure cranny and hybernate there.

Réaumur saw the female ranging her eggs, twenty or more, close to the water on the sides of tanks and the interstices of tubs; and he thought that, although she hovers over stagnant pools, her ova are not dropped into the water. The long-jointed ovipositor is well adapted to fix the eggs on floating plants or anything which may happen to rest upon the surface of the water, or on supports within the mouths of drains. Plate IX., fig. 1.

The eggs number two or three hundred, and are contained in ovisacs disposed in voluminous ramified bundles, one on each side within the abdomen. They largely fill its cavity. At the extremity of the oviducts the uterus is surrounded with adipose matter and fine vessels, which seem to be sebiferous. The eggs become hatched into larvæ, which may be taken often of less than 0·25 inch length.

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* Bull. Bibliog. Soc. Ent. de France. February, 1895.

Mr. C. H. Vine* observes that *Syrphus luniger* lays about one hundred eggs, and that deposition may commence twenty-four hours after exclusion from the chrysalis. These *Syrphus* eggs are fixed on the buds, or under the leaves, of plants on which their living food may afterwards be found.

The adult *Eristalis tenax* moves but slowly on its legs, but when once it is on the wing it flies with rapidity. Obviously it has strong visual powers for objects at a moderate distance; as may be shown if any one attempts to strike a poised fly with a stick. The clever dodging to avoid the blow, and the almost immediate return of the fly to the same spot of sunshine, is common to most Syrphidæ, and wonderfully illustrates the power of immediate response between vision, and the contraction of the wing-muscles. Whilst hovering the fly can rotate its head upon its short neck as much as 180°, and at the same time the body can be dusted and cleansed by the fine tarsal hairs.

The quiet flight of *Eristalis tenax* is accompanied by a hum not unmusical; and which appears to be pitched about the open note, D natural, on the second string of the violoncello. The note varies up and down about a semitone, that is it passes to D flat, and again it rises in tone. If the insect be caught between the fingers, and at the same time the wings be impeded, the hum passes into a shriller note. This note is somehow connected with the alulæ and the halteres, both of which can be seen at the time to be in rapid vibration. The plaintive note, however, is not produced by these wing-adjuncts, for it can be well produced by *Bombus terrestris* and *Apis mellifica*, neither of which has the organs.

J. Künckel d'Herculais remarks that the disagreeable sensation to his fingers when *Volucella bombylans* is imprisoned between them, is such as to cause him to set the insect free. He imagines that the tremors given to a bird's mandibles may likewise cause it to relinquish its prey. He adds that, in common with *Musca* and *Criorhiza*, these flies have thus a defence which is both original and effective.

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* "Predacious enemies of Aphides," 'International Journal of Microscopy.' C. H. Vine. October, 1894.

However, we may remark that many buzzing insects may be found imprisoned alive in the mouths of flying swallows; and that the droning dor-beetles and the fern-chaffers have not yet learned how thus to avoid the fatal snap of our so-called fern-owl (*Caprimulgus*).

From the sound made by *Eristalis* on the wing, the Japanese call the insect "Bum-bum," and we carry the same idea into our word "bumble-bee."

Again, Chaucer has in the "Wif of Bathe's" tale—

> "And as the bitore bumbleth in the mire,
> She laid hire mouth unto the water down."

With reference to noises produced by insects, Prof. Bolivar asserts that the sound emitted by the hemipterous *Phyllomorpha* proceeds from a very rapid vibration of the antennæ,—so rapid indeed that the eye cannot follow the movement. He apparently adopts the theory of M. J. Künckel d'Herculais, who considers these vibrations in Volucellæ to be defensive: "C'est là, évidemment, un étonnant moyen de défense de l'insecte déjà protégé par sa forme si bizarre contre les ennemis de sa race."

With reference to the sounds emitted by the lobster, for which there are special basal antennal muscles, Pouchet regards them either as a means of defence, or "une disposition favorisant l'exuviation," but in what manner exuviation is helped does not appear obvious.

As a rough diary of the appearances of *Eristalis* observed at Haslemere, I append the following:—

The larvæ are hatched from ova twice in the year. The approximate time of pupation is from June to late October. Duration in the pupal condition ranges from twelve days to several months.

| | |
|---|---|
| December, 1893. | A single impregnated female, with numerous ova, taken from a crevice where she was hybernating. She crawled but slowly, having survived the cold of 13° Fahr. |
| March 15th, 1895.<br>April 21st, 1894. | Adults with ripe ova taken. |
| June to October. | Larvæ often taken in pools. |
| End of June to late October. | Commencement and time of pupation. |
| May 18th. | Immature males taken. |
| June, August, to October 8th. | Immature females taken. |
| September 12th to late October. | Impregnated females. |

# III. MORPHOLOGY

## Of the Imago of Eristalis tenax.

It has been well said, though perhaps not very concisely, "that it is by comparison of the particular grades of complication of one organ with that of another organ in the same body,—by considering them in relation to the general nature and powers of the entire animal, together with its relations to other animals, and to the sphere of its existence, that we are chiefly enabled to elucidate the uses of the separate additions which are met with, in following out a series of complexities of a single organ."[*] Thus it will be interesting to note the modifications of a particular organ through which it may pass, necessitated by the new wants of a creature as they rise under different conditions.

Prof. Bohr, of Copenhagen, has recently experimented on the swimming-bladders of fishes; and later in this essay a few considerations are offered as to whether there can be any homology between these

[*] Hunterian Lecture by Sir Richard Owen. 1844.

organs and the tracheal pouches of the larval *Eristalis* and other aquatic insects.

It will be better first to take into consideration the internal parts of the head of the imago, and its organs; and to defer the question of respiration to the description of the contents of the thorax and the abdominal cavities of *Eristalis tenax.*

### (*a.*) THE HEAD.

A vertical section, made in plane with the basal part, exposes two large internal fur-like lobes of a bright red colour. These red masses surround and embed the bulbous part of the optic nerves, one on each side See Plate II., fig. 5. Between these red masses an irregular white substance forms a ring, *h*, embracing the muscular filaments and bundles which rotate the insect's head on its small and short neck. Near this ganglionic ring occurs the channel which leads to the perforations for the proboscis. The optic fibrils are exceedingly numerous. They are in communication with the large bulb above alluded to, and figured in Plate VI., fig. 1*f*. The posterior part of the head is concave where it is in contact with the thorax, and as this last is somewhat convex the head rotates with great freedom. See Plate VII., figs. 4*f* and 5*f*. The epistoma or anterior clypeus is large, and almost conceals the tongue of the fly when folded backwards and forwards. The epistoma is that advanced part of the head which characterizes the prominent portion of the face, at the extremity of which the proboscis is articulated. Plate II., fig. 6.

As before noted, the antennæ are placed on the frons under a small crescent-shaped hood. The large third joint has a minute orifice on the opposite side to the long seta. I cannot explain its import, but I may mention that, as relates to the third large antennal joint of the blowfly, Mr. Lowne states that it contains a sensory organ, "undoubtedly olfactory."

As comparatively we have so little absolute knowledge of the mode of action of the complex machinery of our own sense-organs, there cannot be cause for much wonder that many authors entertain varied opinions as to the functions of such insect-organs as antennæ, palpi, halteres, and alulæ. Sir John Lubbock says, and with truth, that "we really know but very little upon this subject"; and Prof. C. V. Riley remarks that "with the exception of touch; none of the senses possessed by insects can be strictly compared with our own. On the other hand, insects certainly possess senses (such as the faculty of sembling), concerning which we have nothing to compare."*

## *The Eye.*

Careful sections made through the eye bring out its interesting mechanism and with distinctness. Such a section is figured on Plate VI., fig. 1. The anatomy does not greatly differ from similar parts seen in *Musca vomitoria*, but the nerve fibrils which enter the lower ends of the rods in *Eristalis* are longer and more curved before they become part of the optic bulb. Compare figs. 2 and 3. The cones are rather short and very numerous. The facets in most parts of the cornea are hexagonal, but in certain positions they approximate to square figures, but such appearances are chiefly due to perspective.

The structure of the eye of *Melolontha* has been so well described by Straus Durkheim, and that of *Libellula* by Müller, that it will not be necessary to go into much detail with *Eristalis*. Yet a few observations may be given in connection with my drawings from the camera on Plate VI., figs. 1–5.

The facets on the compound eye of *Eristalis* are wonderfully numerous, but on account of the convexity of their setting only a very few lenses can combine to make a definite picture. Plate VI., fig. 1*a* and fig. 4.

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* See "Address on Social Insects," delivered to the Biological Society of Washington. 'Insect Life,' vol. vii., No. 1.

Prof. Mallock has so ably described the functions of the compound eye of insects, that some apology is needed for summarizing his conclusions, and bringing before the general reader theories now well known to the specialist.

The simple eyes of vertebrates form images on a kind of tessellated pavement, formed at the termination of the sensitive fibres of the optic nerve; definition seems to be limited to the distances of these terminations from the lenses which form these images.

In the human eye this limit of sensitiveness is about one minute of arc, the centre of curvature of the retina being considered; that is, no image can appear as two points under a less angle than one minute.

In the above-noted paper it is shown that for a compound eye to be made equal in definition to the human eye, an apparatus like a camera must be constructed of numerous lenses, each of which must be $\frac{6}{100}$ of an inch in diameter ranged round a shell, and that the concave screen to receive the images must be nineteen feet distant. Each lens must also be provided with its own special tube, to prevent the confusion caused by one image overlapping another. A similar effect can be produced by using numerous pin-holes instead of lenses, each aperture of which may be $\frac{1}{25}$ inch in diameter, $\frac{1}{8}$ inch apart, and singly mounted at the mouth of a tube twenty feet long. The use of lenses instead of pin-holes thus would reduce the length of the first compound camera from twenty-five to nineteen feet, but for all practical purposes of course such an apparatus would be useless. The numerous images of different parts of an object here combine to form a very rough picture of the whole; for the lenses can show only that part of the object the rays from which pass axially. These tubes and lenses are shadowed forth in the "rods and cones" of *Eristalis* and other insects. Such are drawn in section, Plate VI., figs. 1, 2, 3, and 5. The bases of these rods are in connection with the retina, behind the pigment of which is the expansion of the optic nerve.

In the experimental and compound camera shadowed above, each tube must have a lens of 0·06 in. diameter, and a diaphragm pierced at its centre with a hole of one minute diameter, placed axially, as in the insect eye.

Dr. Mallock thinks that Müller is most probably right in supposing that the thousand and more images formed from the compound eyes of insects are translated by them into a whole; in the same manner as we recognise only one image from those formed by our two eyes.

It will be seen also from the above, that the shorter the radius the smaller must be the actual minute of arc, and that the curvature of the cornea must have reference to that of the lenses, otherwise the images would not impinge on the sensitive points of the retina. From this curvature of the cornea it will appear that only a few lenses can act simultaneously for any particular part of an object, and thus the vision of an insect must be very imperfect. Theoretically two nerves at least must be present to form two images; that is, two images cannot fall on the same spot to form two sensations. Thus Dr. Mallock likens an object seen by an insect to that appreciated by us and represented in a coarse worsted pattern, held at perhaps twelve inches from our eyes.

A difficulty to be considered is the fact that the cornea of an insect is far from being truly spherical, but we may suppose that the curvature of the portion most useful to the insect is that which will allow the largest number of lenses to come into operation for that particular direction.

The adult *Eristalis* allows good sections to be cut illustrating these essential parts of the insect eye. Some of these details I have shown in Plate VI. The details of the figures were drawn under the camera lucida, and the specimens had been stained blue.

Prof. Riley thinks that, in consideration of the labours of many later biologists, we must conclude "that the compound eyes of insects are better fitted than the vertebrate eye for apprehending objects not in relief or in motion, and are likewise keenly sensitive to colour," though their sensations of colour may be different from those produced on us. It by no means follows that colour is a strong inducement to insects to search for honey, for some of the chief resorts of the honey-bee is to white or even greenish flowers.

The defining power of the eye of *Eristalis tenax* seems to be less than that of the Lepidoptera, but nearly to equal that of *Apis* and *Vespa*.

Dr. Mallock* gives a table showing the powers of vision of various insects, so far as they are represented by their compound eyes. For *Eristalis* :—

| | |
|---|---|
| Diameter of the eye . . . . . . | 0·108 inch. |
| ,, ,, ommatidium . . | 0·0012 ,, |
| Defining power of lens . . . . . . | 55 minutes. |

The varying curvature of the cornea in *Eristalis* may be seen from my camera drawings on Plate VI. They are not diagrammatic, and on that account perhaps they may not always be easy to interpret. Each lens is embedded in a red pigment, which surrounds a clear space behind, and which I refer to the aqueous chamber noted by Durckheim. At the base of this last, the choroid contracts so as to form a small puncture, which constitutes the iris of the eye, and this permits the central ray from the lens to penetrate into the larger chamber behind (the rod and cone). This is said to contain a dense liquid analogous to the vitreous humour. Towards the base the retina is seen, which receives the thousands of nervous fibrils, converging to a dark mass before they lose themselves in the optic bulb in communication with the brain.

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* 'Proceedings of Royal Society,' April, 1894, p. 85.

On the same plate I have figured a section through part of the eye of *Musca vomitoria.* The eye here appears to be rather more simple in construction than in *Eristalis tenax.* The pigmental divisions of the rods are more discontinuous, but possibly this is due to displacement by the section-knife. The rods are proportionally longer than in the Syrphidæ. It will be seen that light passing diagonally through the lenses will be absorbed by the pigmented walls, and only those rays moving in a definite direction will pass through the aperture in the so-called iris.

The three ocelli on the crown of *Eristalis tenax* are very distinct.

### *The Haustellum or Proboscis.*

The most variable secondary characters of insects are those connected with the mouth and the exterior parts of the reproductive organs. The Diptera show great modifications of the labrum and the labium.

Predacious species exhibit these buccal parts converted into piercing and cutting instruments; whilst the vegetable-feeders have elaborate sucking-pads at the end of the haustellum, and special muscles are provided by which honey and liquids are carried partly by a pumping action, and partly by capillarity, to the entrance of the œsophagus. Diptera have no true mandibles.

Weismann says that he has proved that organs no longer in use become rudimentary, and that they must finally disappear from "panmixia," . . . not from disuse, but because natural selection does not maintain their standard structure. He asserts that the mouth-parts of the imago are formed from what he designates "imaginal discs," and that these are quite distinct from the mouth-parts of the footless larvæ of Diptera.

The proboscis of *Eristalis tenax* is complex, and it is not obvious how the different organs operate for the extraction of honey and the collection of the pollen of flowers. The flies embrace the anthers, and empty them by means of the sharp lancet blades of the proboscis; and the honey rises at first through the capillary action of the beautifully looped tracheal vessels which form two conspicuous pads, acting like a sponge, and known as the paraglossæ. Plate V., fig. 1, *tr*.

The haustellum of the imago is usually concealed within the groove of the theca, which is a continuation of the epistoma. In operation this rostrum is thrust forward, the lingua or tongue unfolding itself, by a kind of hinge (*the cardo*).

Much has been written as to the correct assignment of the buccal organs to their homologues in other insects. Parts commonly found in Coleoptera and Hymenoptera are quite absent or suppressed in Diptera. The number of lancets, in fact, varies from three to five.

Burmeister points out that setæ lying within the sheath of the haustellum are moved up and down like the piston of a sucking-pump, and that the juices, as they ascend, are poured into the sucking-stomach through alternate contraction and enlargement of its walls. It may be doubted if this is a complete description of the action of these parts. The honey-bag, as a receiver, in *Eristalis*, probably supplies the wants of the insect in a manner similar to the water loculi in the stomach of the camel.

In *Eristalis* the outer case of the rostrum answers to the labium of the Mandibulata. The labrum, the mandibles, and two maxillæ are converted into the thin flat knives (the laciniæ), whilst other parts are represented by the maxillæ and their palpi or feelers.

The whole proboscis of *Eristalis tenax* is small in proportion to the size of the insect. When folded, it does not reach to the first coxæ. It has a double hinge, and thus it takes but little room when protected by the peristoma. By pressure it may be protruded, when the following parts (represented in detail on Plate V.) can be dissected out.

The maxillæ form a sheath, the apex of which is cleft into six notches. Beneath, two sharp curved sickle-shaped lancets project, which represent mandibles. At the base of the maxillæ, two rather long punctured palpifers show themselves, each having a palp clothed with long hairs.

The structure of the paraglossæ is very similar to that so beautifully shown by Prof. B. T. Lowne in the blowfly. The fringes of looped vessels are striated, and have all the appearance of tracheæ. As the proboscis has been so well described in *Calliphora*, it will not be necessary to say more, than that it forms a fine object for the microscope, or for exhibition on the lantern screen.

It may be noticed that when the *Eristalis* fly is captured, it usually voids from its mouth a quantity of orange-coloured liquid. Probably this liquid is a secretion from the long filiform vessels which may be referred to the salivary system.

## *The Antennæ.*

These organs are small and inconspicuous. They are articulated under a small chitinous hood at the summit of the epistoma. They rise from a minute globular joint, succeeded by another rather larger, and to this is added a third and much larger and pyriform joint. The third joint has a long and fine seta or bristle inserted on its upper and outer side, and on the opposite and inner side a small spot or perforation appears, which might prove to be connected with some sense analogous to hearing.

The antennæ of the male of *Eristalis tenax* is not fimbriated, as is exampled in *E. arbustorum* and some other Syrphidæ. See Plate IV., fig. 4.

## (*b*.) The Thorax.

The mesonotum of the imago occupies nearly two-thirds of the space of the thorax. It is marked by two bullæ or convex prominences, which form attachments to the powerful internal alary muscles.

The pronotum is very small and inconspicuous. The metathorax is crescent-shaped, and principally represented by the scutellum, which is formed of a bent cylinder with rounded ends. This hollow chamber forms part of the respiratory apparatus.

The thorax, when cut vertically across, shows the internal space to be chiefly occupied by two white shining masses of striated muscle, and each mass is divided into nine separate fasciculi, decreasing in size as they approach the floor of the thoracic ring. Plate III., fig. 4*f*. On the outer side of each, two strong fascicles connect the plates of the mesothorax and the metasternum; whilst another bundle connects the mesothorax with the great cubital wing-plate.

The membrane of the wing is slightly brownish in tint, and usually clouded below the costa with a darker stain, sufficiently marked to be recorded by Walker as indicative of varieties β and γ.

The wings are affixed to the metanotum. Their venation has been already described, and their disposition figured in Plate I. The open subcubital cell may be noted as characteristic of *Eristalis*.

The vibration of the wings is effected by the alternate approximation and extension of the different thoracic plates, and not after the manner of a mammalian limb, in which the muscles act on joints through the intervention of tendons and sinews.

The peculiar manner in which many muscular fasciculi of insects operate may be easily exemplified in the powerful muscles which work the claws of the common crab. Here each bundle may be seen, half an inch long and longer, and disposed in parallel series. One end of the fascicle is attached to the inner part of the crustacean shell, whilst the other end is fixed to the thin internal horny lamina, which acts as a support or process of the whole limb.

One large and two smaller openings show the channels through which the dorsal vessel, the tracheæ, and the alimentary tube of *Eristalis* pass into the abdomen. There are also smaller openings, which form passages leading from the anterior end of the thorax into the neck and organs of the head.

Internally the horny cavity of the thorax is divided into three loculi or air-spaces, of different sizes. The largest (Plate IV., fig. 2*p*) has a chitinous convex shining wall, which, like the scutellum, has a pulmonary function. A thin membranous septum divides the cavity longitudinally (fig. 2 *s*); it unites with a white fimbriated mass of muscles, which extend and contract the legs of the insect.

The pulmonary sacs are lined with a delicate membrane (the "intima" of Lowne, as seen in the blowfly). This intima is furnished with tracheal vessels, and in addition to these some exceedingly fine shining capillaries. All these parts are best seen in the recently-killed insect. A removal of the muscular masses is necessary before the organs and membranes can be exposed to view.

I regard the two other chambers, right and left (*p p*), partly as resonators, and partly as respiratory sacs. They are in communication with the two large spiracles or stomata placed under the wings of the insect. The spiracles are long-ovoid, with their apertures guarded by a dense fringe of hair, behind which each spiracle has a membranous curtain, perforated and capable of contraction. Probably the entrance can be securely closed by internal valves, such as are known to exist in the spiracles of *Sphinx* and other insects. Two much smaller openings, bounded by horny rings, may be detected on the lower plates of the thorax.

Viewed from the inside of the thorax outwards, each ring shows a tense shining drum-like membrane. This tympanum recalls to mind the well-known structure or drum of the singing Cicada, which many biologists believe to be sound-reverberators.

Tympanic bullæ are also to be found in other insects. Thus Mr. B. T. Lowne says that the great bullæ developed in *Calliphora* are fitted with large air-sacs, and that they are concerned with the humming sound made by this insect during flight. Similar air-sacs are to be found in the scutum and scutellum of other Arthropoda. They were called by Léon Dufour "aërostats," and they are found in the abdominal as well as the thoracic cavities.

The peculiar strident noise of the singing Cicada is effected by special muscles, and it is quite voluntary; yet it can be also produced in the dead insect, by the slight scratch of a pin on the large sub-alar tympanic membranes, the possession of which organs is confined to the male sex. But there seems to be no sufficient reason to doubt that many insects have some sense of sound conveyed to them, although, like the female Cicada, they may be unable themselves to produce any definite sounds. We can believe that suitable tense membranes respond to air-vibrations like the diaphragm of our telephones. Such membranes are found stretched over the pits in the antennæ of many Aphides, and also at the bases of the antennæ of some crustaceans.

Additional remarks will be made as to the functions of these pulmonary sacs or bullæ when the subject of respiration is considered.

Internally the thorax is traversed by the long plicated chyle-stomach, and also by the attenuated tube which leads from the crop or sucking-stomach. This thin membranous sac is homologous with the "honey-bag" of the bee. Its duct opens into the œsophagus.

The crop is situated in the abdomen of the adult.

The pharynx is embraced by strong broadly striated muscles, and its interior is corrugated, apparently for the purpose of comminuting the pollen grains before they enter the chyle-stomach. Plate III., fig. 4, *d*.

The several organs comprising the alimentary apparatus are drawn in Plate VIII., fig. 2; Plate IX., fig. 3, *c* and *d*.

### *The Halteres.*

When in insects or other animals we find organs very similar in structure to our own, we may legitimately conclude that they have similar functions to perform. If we find that insects possess transparent lenses, rods and cones containing clear liquids of different densities, pigment and perforated septa analogous to the iris of the eye, and also nervous fibrils converging to a mass of brain, we may legitimately think that in a modified form such insects have visual senses. If, on the other hand, we can find no auditory passage in an insect, no tympanum or chain of chitin to represent the otoliths of the ear, and no network of nerves suited for responding to air-vibration, it seems to be little more than guess-work to assign the sense of hearing to such different structures as halteres, palpi, or antennæ.

That sense of some sort is connected with these organs we can little doubt, but such senses may have nothing really homologous with our own.

As to sounds produced by insects, it may be noted that although many are sufficiently grave to be heard by the human ear, there are many too acute, from their rapid vibration, for our hearing, and yet nevertheless they may be quite appreciable by insects. Lubbock says, "We can no more form an opinion of them than we should have been able to conceive red or green, if the human race had been blind." Yet the human ear can in some cases appreciate 38,000 air-vibrations in a second.

Auditory organs of insects seem to have little or no analogy with our own. Prof. C. Riley thinks every minute ramification of the wonderfully delicate feelers of the male mosquito in all probability pulsates in response to the piping sounds of the female.* Doubtless subtle influences are round and about us of which we know little or nothing. Such may react on suitable organs in lower animal life. We can see the effects of such, but we cannot trace their immediate causes.

Although halteres cannot be regarded as balances, for their weight is insignificant, their presence in some Diptera seems to be in a manner necessary to a steady flight. Several observers have shown that insects deprived of them fly with uncertainty, and in an aimless manner.

The halter, or "poiser," appears to be connected with the tracheal system. Lowne thinks that they are part of an auditory apparatus, in which opinion I am inclined to concur, so far only as being receivers of vibration.

The halter, or poiser, consists of a globular somewhat bladder-like head (capitulum) fixed on a long stalk or style, which is dilated towards its base. This capitulum may vibrate in a manner similar to a fully-inflated bladder. The base is fixed upon a strong horny ridge, most easily seen from the inner side of the thorax. The style towards the base is sulcated, and the furrow is furnished with many transverse striated marks. Plate IV., fig. 5 *sc*.

This construction of the halter of *Eristalis* is very similar to that of the blow-fly. Mr. Lowne states that a current of fluid passes up and down the style into the capitulum, and that the sulcated part, or scape, is furnished with certain sensory nerves. These, in

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* The perfectly deaf man has been known to experience pleasure from pressing his teeth on the sounding-board of a harp in action, and solely through the gross vibration passing to the bones of the head. The author also is aware of the interest shown by the deaf in the air-undulations formed by playing on a powerful organ.

*Eristalis*, I have not been adroit enough to expose or to trace, nor the mechanism which causes the vibration of the organ when the insect hums its higher notes.

The deep hum of *E. tenax* is a sound distinct from the peculiar squeaking and plaintive noise made by the insect when caught between the fingers. I have cut off the wings quite close to the thorax, and I found that this shrill note is not sensibly affected. At the same time the alulets and the halteres were seen to be under continual vibration. This shrill note may be also noted in the bee and other insects which are without halteres or alulets.

Much has been written and many theories put forth as to the functions of halteres. Westwood and others considered them homologues of the lost lower wings, whilst others have sought for these last lost organs in the alulæ of Diptera. Their proximity to the large stomata and to the loculi of *Eristalis* may suggest some use in promoting air vibration, something like the action of the reed in the clarionet. But independently of any sound the halteres might cause, we might think that vibrations alone are translatable by insects into some sensation analogous to, but not necessarily identical with, our hearing. The sounds made by insects are obviously so pleasurable to them, that some organ must be present in one or both sexes which can act as a recipient of the air-vibrations produced.

The halter, poiser, or balancer rises from a deep depression under the insertion of the wing. It is covered by a compound scale, which is finely fringed with hairs at the edges. The poiser is seldom still, and even when the insect is nearly dead it shows a continual twitching. If the insect be turned on its back, the poiser may easily be seen at the base of the thorax.

When a section is made across the thorax, the poiser is found to be in communication, though not direct, with a kind of membranous drum or tympanum. It is inserted between two polished hollow bulbs. When the thoracic drum is torn open and viewed from the inside, three oval ridges are seen on the walls, which are the processes to which the poiser is outwardly attached. The poiser may be likened fancifully to the malleus, or one of the bony processes of the vertebrate ear.

The resonating cell, for such I am inclined to believe it to be (Plate IV., fig. 1, *p p*), has a minute tubercle on it, with a central mark or perforation.

An oval opening in communication with these corneous bullæ is in proximity with the great spiracle, but as the plates of the thorax are complex in form, and they are also densely clothed with hair, it is not an easy task to describe their sutures and boundaries.

Diptera and Hymenoptera must have produced their musical humming in geological times long before the mechanism of the vertebrate ear was perfected. The halteres of some of our large Diptera are well developed; nevertheless they show the presence of no such resonators. Many such insects have no perceptible hum, and this militates against the probability for the halteres being concerned in the production of sound.

The observations above were made on living but numbed individuals of *Eristalis tenax*. Although the hind plate of the thorax of one had been sliced off, the insect lived under the microscope for several hours. Occasionally it buzzed with its wings, and twisted its tarsi one with another in the manner commonly seen in most Muscidæ. Another decapitated specimen lived longer; and yet another for twenty-four hours without its abdomen.

### *The Alulæ.*

These membranous scales are large in *Eristalis tenax*, but still larger in *E. arbustorum*. They protect the halteres, and they also cover the air-passages and the large spiracles which admit the air to the loculi.

The principal lobe is circular, or, more correctly speaking, kidney-shaped. It consists of a thin plicated membrane stretched over a stout striated ring, the border of which is fringed with stout hairs. Above this tambourine-like scale there is a smaller fan-like scale, and below these yet a smaller leaflet. All of these membranes are slightly connected, and they cover the halteres without touching them or the wings above. It has been noted by Newport that the halteres, which are fixed to the metanotum, are developed mostly in inverse proportion to the size of the alulæ. These former organs are usually referred to the supposed lost wings of Diptera, and not to the alulæ, which at first might seem to be more suggestive.

### (*c.*) The Abdomen.

This part is formed of four chitinous rings. The first ring is very short, and articulated to the thorax by an almost imperceptible peduncle, with three small openings, through which the viscera pass from the thorax. The second, third, and fourth rings are nearly of the same width, but the third somite is the widest. All the rings are finely fringed at their lower edges, and they are united by an elastic connexivum, which can be partly seen at the sutures near the sides.

The normal number of abdominal rings is represented in the adult female by a long five-jointed ovipositor, with its two valves; and in the male by a somewhat complex pygofer, with papillæ. Plate I., fig. 3. The ovipositor can be protruded at the will of the insect to nearly half the length of the body, as may be seen in Plate I., fig. 1; and IX., fig. 1. It can be retracted out of sight.

The abdominal rings freely telescope one within the other, which enables the insect rapidly to respire and expire the air which passes through the stomata. This quick alternating action is best seen directly after the insect has alighted from a long flight.

The second abdominal ring is transparent, and of a fine golden yellow colour. A dark brown longitudinal line divides the ring, so that the transparent part externally appears like two lateral golden spots. The other rings in *Eristalis tenax* are piceous brown, and nearly opaque.

# IV. PHYSIOLOGY.

## (*a.*) The Alimentary System.

The proventricle and chyle-stomach of *Eristalis* are placed within the thorax, and lie under the great alary muscles; but the proximate and distal intestines (called colon and ilium by some authors), and also certain bundles of sebiferous glands, are confined to the abdomen. Here also, interspersed with an abundance of fatty tissue and permeated with fine tracheal tubes, long tuberculated malpighian loops (renal ?) may be detected; and the remarkable rectal organ, with its four glandular pouches, which Newport referred to the respiratory system.

Each body-ring has its own pair of stomata, but none of these approach in size the two alary spiracles of the thorax. The apex of the abdomen occurs either blunt, pointed, or roundish, according to the sex and the maturity of the insect.

The distal intestine in both the sexes is furnished, just before its termination at the anus, with a large pyriform viscus, having a strong muscular coat. The muscular striæ pass transversely around the walls of this pouch, which is an expansion of the rectum, and show it to be contractile. The distal intestine enters at the larger and upper end; and after expanding into the walls of the pouch it again contracts into a short tube, which ends close to the insertion of the sheath of the ovipositor or else near to the genitalia of the male.

This viscus shows four ring-like papillæ on the surface, each with a black centre, from which from three to five small tracheal vessels run outwardly for some distance. At first they are quite separate from each other; they afterwards unite into one or more larger tracheæ. The tracheæ are of considerable length, and they are bathed freely by the fluids which fill the abdominal cavity.

The above-mentioned ringed papillæ perforate the sides of the rectal pouch; they are continued within in the form of tapering membranous sacs, ending in fine terminations, too transparent to follow with the eye.

Similar glandular bodies are known in *Musca* and in *Libellula*. G. Newport saw a clear pulsation in these glands, and finding them connected with so many and such large tracheæ, he concluded that they belonged to the respiratory system of the insect.

Prof. Lowne at first regarded these organs as endowed with some urinary function, in which Mr. Vine, who has quite recently studied the subject in *Eristalis*, agrees. He substantiates his views by stating that the presence of uric acid may be proved in the liquid expressed from these glands; for if treated with hydrochloric acid, crystals presumed to be those of uric acid can be seen to form under the microscope. If uric acid in sufficient quantity can thus be satisfactorily shown, it will go far to prove the presence of some urinary organ in *Eristalis;* though urea, not uric acid, is the normal produce of the secretion of the kidney.

I do not wish to dispute the position that these rectal glands are or are not renal, but no clear explanation yet appears why these organs are so largely supplied with tracheæ. We might indeed suppose that some oxidation of urea into uric acid takes place through their means, but effete nitrogen does not appear as a rule to be eliminated as uric acid, except in the instance of some reptiles.

Mr. C. H. Vine* has given, in his interesting and recently-written memoir on the predaceous Syrphidæ, some high magnified details of the anatomy of *Syrphus luniger*, and also some good figures of the rectal organs of the insect. By his kindness I am enabled to reproduce his drawing of the intricate and remarkable manner in which the tracheæ ramify over the surfaces of these glands. The result of his researches on the Syrphidæ I believe very closely accord with those of my own, as far as *Eristalis* is concerned. He shows how the pollen grains of flowers are taken up by the proboscis of the fly; that they pass into the proventricle, where their contents are abstracted, and often with so little injury to the cell-walls that the flowers from which the insect has taken them may be identified from the character of the shells of the pollen grains often found undigested in the lower intestines.

The imago of *Eristalis* drinks principally of honey, but it will also imbibe a fair-sized drop of water, if presented to it, after being long in confinment.

The position of the Malpighian vessels of insects is below the proventricle, where their secretions are poured into the intestine. This has led many naturalists to the conclusion, from analogy, that their functions are biliary. Others, seeing them congregated at the rectum, where their extremities in great measure take their rise, have, on the other hand, thought their functions are renal. But we are hardly yet in the position to say that the excreta of insects are similar to those of vertebrates. A satisfactory proof of the presence of cholesterine in the Malpighian secretions, and of urea in the rectal glands of insects, will go far to settle the question as to the significance of these organs in insect economy.

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* H. C. Vine, "On the Anatomy of the Aphis-eating Syrphidæ." 'International Journ. of Microscopic Science,' 3rd ser., vol. iv., Oct. 1894.

Prof. Poulton, in 1894, showed that the caterpillar of the lackey-moth secretes yellow crystals of lime-carbonate from its Malpighian glands. These crystals, as a yellow dust, obscure the texture of the silken cocoon, and protect the chrysalis within.

From recent remarks made in 1892, by Prof. Lowne, it would appear that he hesitates, or modifies his previous opinion that the rectal glands of *Calliphora erythrocephala* are renal in their functions.

All the principal viscera, both male and female, will be seen figured in Plates VIII. and IX. of this memoir.

### *The Malpighian Vessels.*

Dutrochet as early as 1818 noted certain glandular tissues attached to the stomach of *Eristalis tenax*, and found them both in the larva and in the imago. He regarded them as bile-secretors. He also established the existence of salivary vessels in the larvæ, but he thought their function was lactiferous, "destined to serve towards the nourishment of the nymph during its metamorphosis."

Four long bright greenish tubes studded with tubercles proceed from, or rather open into the anterior end of the proximate intestine. These vessels, known as malpighian, have their origin near the anus, and are of considerable length, intervening and overlapping most of the viscera, even to the tail-end of the larva. They run in close proximity to the chyle stomach, below which they empty their secretion. Plate VIII., fig. 2, *m*; and IX., fig. 3, *m*.

Much discussion has arisen as to the nature of the fluid secreted by them. Newport leant to the belief that it was of a urinary nature, and he regarded the vessels as renal.

These beaded tubes are very long in the adult

*Eristalis tenax*, forming loops as they become reduced in diameter and as they descend, and terminate, so far as I have been able to trace them, in blind ends. Plate VIII., figs. 7 and 8.

Interspersed with the viscera of the larva, short tubes of a bright red colour here and there permeate the body, the significance of which I am ignorant. They contain a transparent homogeneous liquid without visible corpuscles. The liquid appears to be identical with that found in the larvæ of certain gnats which go commonly by the name of blood-worms.

The anal opening is oblong, and surrounded by eleven leaf-like flabellæ with constricted apices. Each flabellum encloses a doubly forked vessel, which appears to be connected with the tracheal system. These organs may represent the rudiments of the curious rectal glands of the adult fly. The flabellæ are charged with granular matter, and surround the anus like the petals of a flower. Plate I., fig. 5, *a*; and Plate III., fig. 8.

Already our knowledge has been increased by the study of the larval changes described in the fine monographs of *Sphinx*, by Newport; *Calliphora*, by Lowne; *Melolontha*, by Straus; *Volucella*, by Künckel d'Herculais; and also by memoirs of more recent date like that of *Dicranota*, by Miall and N. Walker.

The internal organs of the larva of *E. tenax* are not easily unravelled. The principal muscles used for progression interlace, and are intimately connected with the outer integument; but if the larva be plunged into boiling water, and be allowed to cool slowly, the integument can be dissected off without much difficulty. The organs, however, have many attachments; and besides they are entangled with the membrane which invests the voluminous fat-vesicles supplied all over the body of the grub.

The best method, I find, for examining the viscera is to snip off the head and tail of a maggot, and to slit it down the ventral surface. The integument can then be pinned back under water with the finest of entomological pins on a sheet of weighted wax. When a full-fed larva is thus snipped, a large quantity of milky fluid escapes and clouds the water, rendering it quite opaque with granular and oily matter, which has escaped from the chyle-stomach.

The external appearance of the head has been already described. Within, and in the neighbourhood of the mouth, a number of delicate fibrils as long or longer than the body of the larva are seen. They form loops or thread-like vessels close to the buccal orifice, and doubtless assist in salivation. Plate IX., fig. 3, *s*. The orifice, with its garniture of horny teeth, is shortly connected with the pharynx. The upper part of the œsophagus is purse-like, and has the internal transparent walls thrown into folds, but only on one side, like the flutings of a bellows. Plate III., fig. 4, *d*; and VI., fig. 6, *ph*. The folds unite at the bottom, and are surrounded by a neural mass before the pharyngeal pouch debouches into the convoluted chyle-stomach, which is the viscus charged with the milky fluid above noted.

The walls of the proventricle or chyle stomach are studded with minute punctures or dots, which possibly are glandular, or they may prove to be only epithelial scales. Plate VI., figs. 6, *ch*, and 7. The chyle-stomach joins on to the proximate intestine. This last part of the canal varies in diameter and form, according to the amount of dark nutritive matter it may happen to contain. It lies under and between the two great tracheal trunks, and after folding back, it returns towards the head. Finally it joins the distal intestine, and the colon before it terminates at the fimbriated anus. Plate VIII., fig. 2; and IX., fig. 3, *a*. The distal intestine is very long and difficult to isolate from the adipose matter which naturally obscures it. When cleared of such fat it appears as shown in Plate VI., figs. 6 and 7. Although the distal intestine is often seen distended with fœcal matter, I have never witnessed the larva evacuating the same.

### *The Larva.*

In many respects these internal organs differ from those of the imago. The great air-trunks of the larva lose their extremities close to the roots of the contractile cornua; but, as pupation approaches, the connections become more evident, and finally clear passages are made to their summits. The tracheal trunks rapidly enlarge their diameters as they pass down the sides, and they get their greatest expanse at about the first third of the length of the larva. From this point they gradually again taper down to the neighbourhood of the anus, where they have their continuance in the long tortuous tubes running throughout the length of the so-called tail.

## (*b.*) THE RESPIRATORY SYSTEM.

Air is brought to all the organs of the bodies of insects, larval as well as adult, through the tracheæ. Vessels of all sizes, some of which only can be seen through highly magnifying lenses, spread over the walls of the stomach, intestines, muscular masses, organs of the mouth, and even penetrate the chief nervures of the wings.

Tracheal vessels intermingle with the ovarian follicles, and are connected with the glandular organs attached to the rectum of the fly, and the anus of the larva. The great pulmonary sacs are lined with them, and also the membrane of fine network, white and glistening, seen within the recently-killed fly. Even the adipose cells through their investing membrane are permeated by them and numerously.

The parallel trunks so conspicuous in *Eristalis* probably may be traced in the larvæ of all Diptera. They are easily seen in the Tipulidæ, Culicidæ, Muscidæ, Volucellæ, and the Syrphidæ generally. *Œstrus* and *Dicranota* have them distinctly developed. In aquatic dipterous larvæ the tracheæ almost always end in caudal or thoracic spiracles. As a general rule abdominal stomata are absent in dipterous larvæ, though in *Eristalis tenax* the exuviæ or last moult of the larvæ shows them in an aborted or non-effective form.

The swimming-bladders of fish have long been referred to parts of their respiratory systems. Although these organs are thought to be chiefly utilised as means for altering their specific gravities in water, they certainly conduce to the aeration of their blood, and as such they act as pulmonary reservoirs.

Prof. Bohr, of Copenhagen, in 1894, found that the swimming-bladders of some sea-fish are capable of secreting out of the air contained in them, as much as fifty-two, and in other cases even eighty, per cent. of oxygen gas. Probably this action would be more correctly represented as an elimination of nitrogen from the air enclosed in the swimming-bladders than as a secretion.

These great air-sacs may thus be regarded, not as secretors but as separators, allowing the blood of the fish to become oxygenated through the capillaries spread over the surface of the bladder.

There would seem to be some analogy between these bladders and the pulmonary sacs of aquatic and even of flying insects. The larvæ of *Eristalis*, like fish, store air for more purposes than one. It is certain that the air contained in their great tracheal trunks is not there secreted. The quantity, however, is too small to prove with any certainty by analysis that it is richer in oxygen than what is found in atmospheric air.

It is remarkable that these tracheal sacs are in several places embraced by much smaller tracheal vessels, as in Plate VI., fig. 6. Whether these employ the former as mere supports or whether they anastomose into the larger is undecided.

The tracheæ in the Hymenopterous Bombidæ are dilated into an immense number of minute vesicles, which allow not only of the most extensive respiration, "but they render the body lighter by enabling the insect to alter its specific gravity in flight."* Such vesicles are only dilated tracheæ.

### *The Imago.*

The principal tracheal trunk on one side of the abdomen of the imago always anastomoses with that of the other side. Smaller transverse branches run across near to the inner edges of each body-ring, and in proximity to the connexivum.

According to some observers, just before insects take flight, air rushes into the thoracic and abdominal air-chambers. This is effected by the expansion of the walls of the body-rings, similarly to the action of the ribs of Vertebrata in the act of breathing. The valves of the spiracles are closed by muscles, which I have clearly traced in *Eristalis*. The thoracic and sternal plates are next put into rapid vibration by means of the powerful depressor, elevator, and protractor muscles, as figured Plate IV., fig. 1; and VII., fig. 9, and the insect rises into the air.

There is some difficulty in wholly accepting Newport's explanation of the action of the pulmonary sacs found in many volant insects. Tracheæ are bathed in the nutrient juices of insects, and oxygenation is effected through their walls. The pulmonary sacs of the adult *Eristalis* and *Volucella* are not so bathed; and if oxygenation is effected through them it would seem to be by some action on the capillaries of the intima spread over the chitinous and comparatively dry walls. The form of these capillaries requires at least an eighth-objective to show them at all satisfactorily. I rather regard them as conveyors of lymph, or else of colour-less insect blood to the sacs, just as blood is aerated in the fine and delicate lung-sacs of the Vertebrata.

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* With reference to the functions of these air-sacs, see G. Newport, article "Insecta," Todd's Cycl. of Anat. vol. ii. p. 984, *et seq.*

There are usually nine pairs of stomata on the abdomens of insects.

A transverse section of the abdomen brings into view a remarkable vertical membranous septum, passing down the medial line; which thus divides the body-cavity into two portions; the upper part of the abdominal cavity is almost devoid of viscera, and nearly empty. This septum can be most easily seen if the section be made longitudinally, and a little out of the direction of the medial line. The septum is corrugated and thrown into folds, as if it were elastic, and capable of alternate distention on one side and then on the other. Plate VIII., figs. 3 and 5.

The inner part of the basal wall of the first abdominal ring, *viz.*, that part which is in communication with the thorax, is the support of a singular fascicle of muscles disposed in fan-like laminæ, with fringed edges. These project into the pulmonary cavity, like gills. They are accessory to the rapid motions of the abdominal rings before mentioned. Plate IV., fig. 3, *r*; Plate VIII., fig. 3, *f*.

The second ring almost exclusively consists of two pulmonary chambers filled with air, and lined with exceedingly fine capillaries having the appearance of striations. The chambers are also furnished with large tracheal branches running to the stomata. There can be no reasonable doubt that these air-chambers are connected with the respiratory system. Possibly also they may act like the wind-sac of the bagpipe in forcing air through some orifice to form the humming sound of the insect; compression being effected by the muscles connecting the somites.

These pulmonary pouches are still more developed in the *Volucellæ*. *Volucella pellucida* is so named from its remarkable transparent air-pouches on the upper parts of its abdomen. Like *Eristalis tenax* it has also the elastic septum which divides the pulmonary chambers. M. J. Künckel d'Herculais calls these pouches "ampoules trachéalles."

Experiment bears out the fact that the most active respiration is connected with high irritability of temperament, and this also involves a corresponding rise of temperature in insects as it does in the higher animals. A familiar example is the rapid rise of temperature in the bee-hive at the time of swarming. As many as one hundred and sixty movements per minute in the abdomen of the humble-bee (*Bombus*) have been counted; and in the little irritable wild bee *Anthophora retusa* G. Newport counted many more, namely, two hundred and forty movements. During the torpidity of insects much less oxygen is consumed, and the body-tissues are less rapidly wasted.

The dorsal vessel of *Eristalis* lies under the rings and on the back of the imago, and the slender convoluted alimentary tube, with the crop and other viscera, lies on the ventral plates. The large ovarian sacs, containing several hundred eggs, cover the upper part of the abdominal cavity. The testes and other parts of the male are principally located in the last abdominal ring.

### *The Circulation.*

The existence of a pulsating heart has been proved by Straus-Durckheim, Carus, Burmeister, and others, and its presence proves that a circulation more or less complete, and perhaps through vessels, really exists in insects. Circulating vessels indeed may be seen in the branchiæ of Ephemeridæ, and in the wing-veins of *Chrysopa*. I have not succeeded in dissecting out the pulsating or "supra-spinal cord" of *Eristalis* as seen and described by Newport in other insects. Such an organ seems to be necessary for driving the blood to the walls of the intima or lining membrane of the pulmonary sacs. A pulsating vessel driving the animal fluids from the tail to the head may, however, easily be seen in the larva of *Eristalis*.

## (*c*.) THE REPRODUCTIVE SYSTEM.

### *The Male.*

As to the male organs, but little here can be advanced beyond a few remarks relating to the external parts. Like those of many insects these secondary sexual characters are rather complex, and beyond the conjecture that certain of them are used as claspers or retainers during the union of the sexes, whilst others act as irritators or excitors, I can offer as to their functions little that is new.

It is now very generally agreed, that the stings and ovipositors of insects are modifications and representations of the eighth and ninth abdominal somites. The particular somites or body-rings of the females, however, are not always those found to be the same as those modified in the males.

Discussion has been long as to how many divisions should be regarded theoretically as belonging to the abdomen of an insect. In the male of the blow-fly only five visible rings can be counted, so here the missing somites must be either suppressed or find representation in the processes and plates of the sexual armature.

The external parts of the male *Eristalis* consist of a rounded apical process furnished with two bent and blunt papillæ (the "parapalpi" of Lowne), tipped with black, and armed with stiff bristles. Besides these there are one or perhaps two pointed styles or narrow valves (hypopalpi), between which the short penis can be extruded.

Internally two globular vesicular testes are seen, each with its vas efferens, which together join in a common duct, the vas deferens. These organs are placed under the dorsum of the fourth segmental ring, and they end in an ejaculatory duct at the commencement of the penis, close to the rectal pouch. Numerous delicate fibrils coil round the interior of this last somite, near the anal plate. For these parts see Plate VIII., fig. 2, and fig. 4, *r*.

The penis itself, which I have not myself distinctly dissected out, has been drawn by Mr. C. H. Vine, who very kindly allows me to describe from his drawing. The penis of *Eristalis tenax* consists of a short tube, which expands into a trumpet-shaped mouth covered with minute recurved hooks. Above these there are two pairs of much stronger hooks, which doubtless act as retainers of the female during couplement.

The males are very common during the last two weeks of May and throughout June; but the greater number that I have examined at that season have very diminutive reproductive organs; and the individuals appear to be, as relates to the sexual apparatus, only partly developed. The bodies of the males appear to become more gravid and plump as the late autumn females come on the scene, when copulation is effected.

### *The Female.*

The abdominal rings of the adult fly can undergo much distention, and the apical rings in the ripe female are nearly globular. The external organs are less complex than the male. In the long ovipositor, and its terminal valves or plates, we have a more obvious representative of the somites, missing in the abdomen, than in the male insect; but here, as in the joints of an insect's antennæ, it is not easy to decide whether a simple constriction should be accepted as a joint, or neglected on the score of its rigidity.

The ovipositor, as figured on Plate IX., fig. 1, has four distinct joints, with a constriction on the third. The fourth member ends with two long valves densely clothed with hair, and the anal aperture seated on a papilla clothed with bristles. The soft membranous tube, which is an elongation of the vagina, runs parallel to the duct within. The oviduct is protruded during the process of oviposition, and probably its soft extremity assists the insect in the selection of the exact place where the eggs should be laid.

On each side of the oviduct long tubular vessels can be traced to glandular sacs within the abdomen, which secrete some lubricating material useful in the passage of the ova. A gentle pressure indeed forces forward, under the microscope, a crowd of granulated cells mixed with an abundance of oil globules.

The horny ovipositor, when exserted, may measure as much as 0·60 or 0·75 of an inch. It is furnished at the extremity with the anal and the vaginal orifices. The apparatus thus affords a good illustration of that variation of form in the female parts which Burmeister designated the "vagina tubiformis."

The shapes of the ova somewhat differ. I have taken females full of ova in early spring, in which the eggs were fusiform; again, I have examined others in late autumn, in which the impregnated ova were oval or almost globular.

I have no proofs to the fact, but I believe that the fusiform ova produce the larvæ which develop the numerous imagos with incomplete reproductive organs; and that such flies do not oviposit. See Plate IX., fig. 3, *o*; and fig. 2, *st*.

As a rule, the ova of insects deposited in water are not furnished with glutinous coats; on the other hand, eggs fixed on the upper leaves of water-plants are generally covered with some kind of glutinous and adherent matter, unaffected by water. Possibly the vessels marked *sb* on Plate IX., fig. 3, may be appropriated to the secretion of such a varnish.

Perhaps all the females disclosed in late October with oval eggs retain them through the winter, and deposit them early in the following March or May. They give rise to the numerous small larvæ then seen on the stagnant water and pools containing suspended organic matter. These little maggots are not more than 0·12 of an inch long, yet though so young they show distinct indications of a complex tracheal system.

The ova lie on the back of the female adult under the integument and in two bundles, ranged in parallel rows. Each fascicle contains perhaps a hundred eggs. The bundles unite by forked tubes into two large oviducts, one on each side, before they enter the uterus, but the ova in passing become fertilized through the secretion furnished by the two spermathecæ attached to the upper part of the uterus. Plate IX., fig. 3, *sp.*

The sperm vessels are two rounded or pyriform pouches mounted on stout pedicels, through which the secretion issues. Whilst in *Eristalis* I have only found two sperm receptacles, Prof. Lowne discovered three in *Calliphora.* The uterus is rather large, and is attached to the muscular tube constituting the elastic oviduct which is enclosed in the ovipositor, above described.

With care the ovarian follicles can be unravelled, but the tenderness of the investing membrane makes it almost impossible to set out their attachments *in situ.*

The membrane or tunic which invests the mass of ova was early noticed by Swammerdam in the allied genus *Stratiomys.* Besides this membrane the ova are kept in their places by a fine network of tracheæ, as has been noticed in the case of other insects.

The ova are found to have attained a considerable size in April. On the 21st of that month they had undergone segmentation of the yolk. As the male does not hybernate (at least I have not observed them till near the end of May), fecundation must have been effected in the autumn previous. These females certainly survive the winter. I have found them crawling out of their hiding-places on a sunny winter's day, and on one occasion I captured a female full of ova in December, 1893, after she had survived the previous low temperature of 10° Fahr., or 22° below freezing water, of that severe year.

Mr. H. C. Vine finds three spermathecæ in the adult

*Eristalis tenax*, viz., two on one side and one on the other side of the uterus. He figures each of them as consisting of a dark brown opaque chitinous capsule, nearly spherical in shape when fully expanded. Each is surrounded by a layer of cells covered more or less with a wrinkled membrane. This entirely agrees with my own observation, except that I have failed to find more than two sperm receptacles *in situ*. These I have figured *in situ*, Plate IX., fig. 3, *sp.*, but they are oval in form, possibly from their contents being less voluminous than those noted by Mr. Vine. Again, instead of the ducts proceeding from them being remarkably long, and, as he describes them, equal to 0·25 of an inch, my example shows each of the spermathecæ attached to the uterus by a much shorter perforated pedicel, close to the entrance of the oviduct.

On the other hand, I have twice dissected females with immature ova in June, with no *developed* long ovipositor, in which three oval bodies, noted by Mr. Vine, were very distinct. Before reading that gentleman's memoir, I hesitated to consider these bodies as spermathecæ, partly from their diminutive size (only 0·01 inch by micrometer), partly from the great length of their ducts, and partly from my inability to trace these ducts to the uterus, or to the termination of the oviduct. The nuclei of these bodies also were hard, inelastic, and chitinous in texture. They were surrounded with a thick and transparent coat, which became of a pink colour under the action of weak solutions of potash. I could not satisfy myself that they contained sperm-cells, but these minute bodies are not always easy to identify. The length of an ovum of *E. tenax* is at least 0·04 inch, therefore it is considerably larger than these bodies.

If it be asked what then are these three bodies, perhaps the best answer, if one must give one, would be in accordance with Mr. Vine's views, though more light is wanted to set this subject at rest.

## (*d.*) The Nervous System.

### *The Larva.*

This part of the morphology of insects has been so ably and fully worked out by George Newport that, except through the hands of a more adept dissector than myself, but little will probably be added to our knowledge in this direction for some time to come.

Newport has given us elaborate and full descriptions of the nervous apparatus of *Carabus*, *Timarcha*, *Acrida*, *Sphinx*, and *Vanessa*, but he has said little concerning the sensory system of the order Diptera.

To those who would work on this difficult branch of morphology as restricted to Diptera, I would commend a study of what M. Künckel d'Herculais has written on the nerve masses of Volucellæ. The description given in his memoir before cited, will in a manner show what we might expect to find in *Eristalis*, a *Syrphus* so closely related.

I will therefore content myself with the following general remarks, which necessarily must be of the baldest description and of an elementary character.

Roughly speaking, the brain of insects may be described as consisting of two knotted parallel cords, situated on the ventral portions of their bodies. As a rule, these ganglia or neural knots are farther apart and more distributed in the larva than in the imago. As the larva grows, the ganglia tend more and more to coalesce, and to approximate the head and thoracic parts. This, however, is not invariably the case, for in *Œstrus* the cephalic ganglia are largest in the maggot-like larva; and the same remark holds good in *Eristalis tenax*, where the brain is large, and forms its principal masses below the pharyngeal pouch. The neural cord is continued a short distance down the belly of the maggot, giving off numerous nervous filaments. As I have not been fortunate in tracing these, I may be allowed to quote Burmeister, from whose figures I also borrow my drawings relating to the larva and imago:—

"The ventral cord commences with two branches, which spring from the large cerebral ganglion lying over the œsophagus. These branches, which embrace the œsophagus, unite beneath into one flat tolerably broad nervous cord, which extends to about the third pair of false feet on the pectoral side, within the thoracic cavity, and here they obtusely terminate. On each side of this cord there are from eight to nine small ganglia, whence the nervous filaments, as also at the obtuse apex of the cord, radiate posteriorly. The last, proceeding from the end of the cord, are the thickest; they extend downwards to the end of the abdominal cavity, and here distribute themselves with their terminal branches to the colon, and the convoluted tracheæ lying at the end of the abdomen." See my drawing, Plate VII., fig. 1, after Burmeister. The cephalic ganglia of the larva may be seen below the pharynx. Plate VI., fig. 6.

## *The Imago.*

The nervous cord of the imago also is ventral, and more specialized than in the larva. Besides the cephalic lobes there are three large ganglia. Two cords join with the thoracic, proceeding from the head. The thoracic brain then gives off nerves on each side, which supply separately the first, second, and third pair of legs, and the muscles which work the wings. Below these, filaments run down to supply the abdominal muscles.

From the first abdominal ganglion, nervures divide and subdivide to supply the chyle stomach and intestines; and from the second ganglion, which is larger, three separate pairs severally go to the reproductive organs, the ovipositor, and the neighbouring abdominal parts.

Theoretically each segment of an insect should have its own special ganglion, but often some are suppressed, and others appear in the form of mere fibrils. The theoretical thirteen ganglia are thus distributed in dipterous insects : two in the head, three in the thorax, and eight in the abdomen.

Künckel d'Herculais figures the head of the larva of *Stratiomys* with a large bilobed mass near the pharynx; and below it and continuous with it eight or more ganglionic masses, decreasing in size and giving off pairs of nerves to each somite.

There are large optic ganglia and nerves in the head of *Eristalis tenax*, portions of which may be seen in connection with the eye. Plate VI., fig. 1.

As an insect approaches its final metamorphosis, the changes in its nervous centres, particularly during pupation, become very rapid. Newport watched these changes in *Vanessa urticæ* continuously every forty-eight hours ; and he published numerous drawings to illustrate its metamorphoses during eight days of August.*

We are prone to realize the lapse of time and mark it by the sequence and observation of phenomena, and we think an event is sudden or otherwise accordingly. We feel a sense of bewilderment when we reflect that almost the whole of the elaborate organization of the *Eristalis* larva dissolves into a creamy paste in the puparium before the organs of the adult can be developed out of it. The organs of the one are not necessarily nor even commonly elaborated from those of the other. Also a contemplation of such radical changes as are effected in the Ephemeridæ in a few hours might almost puzzle the mind as to the meaning of the identity of the individual.

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* Todd's 'Cycl. of Anatomy,' vol. ii., art. "Insecta," p. 963.

# V. HISTOLOGY AND DEVELOPMENT OF ERISTALIS.

## (*a*.) HISTOLOGY.

Although it is out of the scope of this essay, which is intended for the general naturalist rather than for the adept biologist, it may be thought that some remarks should be made as to the Histology and Development of the Drone-fly. Therefore the following very general considerations are added, without any attempt to discuss fully these difficult, and to many, abstruse points.

I have not investigated the histological bearings of these parts with sufficient microscopic powers, but I may summarize the remarks of M. H. Viallanes on the elastic tissue of *Eristalis tenax*, published in 1884.* He comes to the following conclusions with reference to the movements of the caudal respiratory tube of the larva, which I summarize :—

The tube is formed of three cylinders, which can be shortened or lengthened at the will of the animal. This elongation is effected by the contractions of the body, by means of which, fluid is driven into the tube. Its shortening is, however, chiefly effected by special muscles and internal elastic bands. Each of these elastic bands is formed by a single cell, which is so constituted as to act like a strip of caoutchouc. The cell is fusiform in shape; and, while one of its extremities is attached to the neighbouring integuments, the other is prolonged into a process which is fixed to the surface of the inner respiratory tube. The cell and its prolongation are invested in a membrane which is of some thickness, but very elastic. At the centre of the cell there is a very large spherical nucleus, surrounded by a quantity of protoplasm, which is also found in the prolongation. Within the tube itself there is a long elastic fibre developed, similar in its physical properties to those seen, for example, in the cervical ligament of a mammal. It is folded many times round the nucleus, and it passes in a straight line through the prolongation of the cell, to the extremity of which it is attached. By the other end it is fused into the protoplasm of the cell. When the cell is drawn out the coiled portion becomes unfolded.

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* See 'Comptes Rendus,' 98 (1884), pp. 1552 - 3.

M. Viallanes continues, that these facts are of interest, as proving the high degree of complexity that may be attained within the limits of a single cell; and as throwing a new light on the morphology of elastic tissue; since they show that this may be developed, as in vertebrates, in the intercellular substance, or, as in *Eristalis*, in the protoplasm itself.

It may be noted that striated muscular tissue presents analogous variations. These long elastic threads may be seen running parallel to, and quite distinct from, the double trachea. I have represented them in the small portion of the respiratory tube which is drawn on Plate VIII., fig. 9.

The great tracheal trunks are transversely connected with each other by cross tracheæ, and a tuft of small tubes is given off to the seat of each false foot. The caudal end of the larva is occupied by a complex zigzag folding of the ends of the great tracheæ before they enter the long telescopic tube ending with the spiracle. Plate II., fig. 1.

The last joint with the parallel tracheæ can be forcibly extended to the great length of five inches. The young larva of *Eristalis arbustorum* dropped into warm water usually shoots out this joint like a dart. When this respiratory tube is at full length the larva can coil it into knots without producing any kink or obstruction to the passage of air within. Plate III., fig. 8.

During the growth of the larva a large quantity of fatty material is stored up, and this is consumed during the elaboration of the organs of the imago in the puparium stage. George Newport regarded this nutrient matter as the product of organs acting as lymphatics. The adipose sacs are enclosed in a delicate membrane, somewhat like the omentum. The sebaceous sacs are soft, and when crushed they yield a large quantity of transparent oil. Some autumnal oviparous females preparing to hybernate Oct. 30th were observed to be so stored with this oil that it could be expressed from their tails in minute drops. By the action of aqueous potash the cyst-walls are broken up, and the oil-globules can be run together. They are not easily saponified except by an alkali and heat.

We would wish to know what tissues of the larva are those which gradually pass into the organs of the adult insect; and also which are those that disappear, or at any rate break up to form, and often in quite different parts of the body, the structures of the imago.

We know that the tegumentary and appendicular parts of the adult are elaborated at the expense of those of the larva; and that the most remarkable modifications are hastened at the times of the insect's moulting, and at the period of pupation.

In the words of M. Künckel d'Herculais, when speaking of *Volucella*, all the organs depending on the tegumentary system "pour la première fois aussi bien que les organes qui doivent être appropriés aux usages essentiellement différents de ceux qu'ils avaient dans la larve, sont cachés dans cette larve sous forme de replis de l'hypoderme, et se développeront par épigenèse à l'époque de la transformation en nymphe."

I do not attempt to prove that these facts, now so generally admitted with reference to other insects, are true in *Eristalis*, and perhaps the task is scarcely needed, since competent hands have recently gone into these difficult details with regard to the histology of other Diptera.

As regards the organs of an aquatic dipteron, we may summarize some of the observations made by Prof. Balfour with reference to *Corethra plumosa.*[*]

The external organs of the imago are produced from certain outgrowths, which are accordingly called by Prof. A. Weismann "imaginal discs." The "wings are formed from two posterior dorsal discs, and the hypodermis of the larva passes directly into that of the imago."[†]

The internal organs undergo a general disruption or breaking up, except that, to a certain extent, parts remain of the generative, nutritive, and the nervous systems.

The organs of the larva, as before mentioned, mostly degenerate into fatty masses, which often take the outward form of the original organs; and these fatty masses provide material from which the new organs are elaborated; whilst certain nucleated cells constitute the initiative centres of growth. Even the tracheal trunks break up to form new trunks, and new branches are elaborated for general distribution.

In *Musca* the abdomen of the larva becomes bodily converted into the abdomen of the imago, but the epidermis and parts of the head and thorax are formed within, and independently of the epidermis of the larva. This is simply thrown off, and has no share in developing the epidermis of the adult.

It thus would appear that few original cells of the larva form parts of the organs of the imago, but that they are represented only by the "descendant cells" of such.

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[*] See Professor F. M. Balfour, 'Comparative Embryology,' vol. i. pp. 350 - 357.

[†] 'Entwicklung d. Dipteren,' Prof. A. Weismann; Prof. J. B. Lowne, as to 'Histology of the Reproductive Organs of the Blow-fly,' p. 673, *et seq.*

### (*b*.) A Possible Development.

Ascertained facts in morphology must be regarded as means to the solution of physiological phenomena. The biologist will feel that the interpretation of form must be based on physiology, or, as Prof. M. Foster puts it, on a molecular basis.

Whatever this molecular basis may be, the philosopher strives to know what are the forces which govern these molecules, and what governs the selection which is obviously necessary to the building up of parts. Again, the metaphysician asks, why materials are to us links between volition and physical action; but hitherto no success has come from attempts to arrive at a rational conception of the abstract *vis viva* of an energy—the *deus ex machina.* Such necessary facts are only to be recognised by abstract faith.

Evolution has been formulated as "a general name for the history of steps by which the world has come to be what it is." It is a description of the sequence of phenomena—knowledge of which is conveyed by our senses; but the cause, from a view purely scientific, is hidden from us.

The theory of evolution, like that of vibration and undulation, is accepted as a good working basis, which offers certain premises. Without some kind of premises no physical science can hope for progress, or be reasoned on by us.

Although mere speculation adds little to our knowledge of natural phenomena, imagination within limits may be often permissible and even desirable as a help in directing experiment.

Recently we have been called on to remember that "philosophers have mined for treasure in many directions, and that the whole field of speculation seems littered with the dross and cumber of their abandoned workings; but though they have not found the ore they sought for, it does not therefore follow that their labours have been wholly vain." But facts should support hypothesis, and not hypothesis control facts.

Some minds are satisfied with a slender amount of proof, and proof of such a character that others will discard it as utterly insufficient for the purpose. One observer thinks it probable that the tan-coloured spots to be seen over the eyes of some domesticated dogs are somehow protective, and that they act as false eyes; in fact, that they give warning to the unwary prey that such dogs are watchful, though really they are asleep.* But on the principle that acquired characters are not retained if they be useless or detrimental to the owner, the tan spots should disappear, for the above presumed gain must alone be to the natural prey, whilst the dog, the elaborator and possessor of these pseudo-eyes, accordingly must often go supperless.†

On the other hand, another investigator may demand too exactingly a complete linkage of Palæozoic types before he will accept a sequence in specific morphology. Still the enquiry of a conversion of species, if there be such a process in nature, is a legitimate and worthy study for the biologist.

The following remarks have somewhat the character of guess-work, but nevertheless they may be permitted as showing one line of conjecture as to how the tracheal system of a terrestrial *Syrphus* might degenerate in its larval stage into an aquatic form.

Larvæ may be regarded as fœtal stages brought about by the influence of varied surroundings. Whilst the fœtus is entirely dependent on the parent for sustentation, the larva comes into existence not only independent, but endowed with powers of development and capacities for accommodation to its environment. Such conditions are not required by the fœtus, which has no necessity to find its peculiar food.

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* See 'Nature,' April 4th, 1895, p. 533.

† It is not clear which are the enemies against which the wild dogs are to be protected. Are not the dogs the aggressors?

The power of variation within limits is more evidently shown in the embryonic periods of life. Thus it is that larvæ and most young animals, on account of their powers of adaptation, can sustain mutilations which would be fatal to them if their organs were already matured.

Adverse surroundings may be successfully combated by larvæ, and we may therefore conceive that certain organs may become profoundly modified so as to meet the requirements necessary for the struggle in life. The study of larval history thus will appear to become more and more important as these facts are generally admitted.

In a certain sense we may consider that the true birth of an insect dates from the time of its exclusion from the chrysalis, and not from its hatching from the egg; for the individual in its perfect form is not seen until the close of the last metamorphosis. The greater part of an aquatic insect's existence is thus spent in preparing for its short season of aerial life, ending in the phenomena of reproduction.

Since in the larvæ and pupæ the advantages are chiefly prospective for the imago, the functional adaptations which confer such advantages surely must be purposive. If this be admitted, it cuts away all attempted explanation of the facts by the idea of fortuity; if such an idea can appear to have any basis at all for argumentation.

But first, we may ask, have the aerial sun-loving dipterous flies risen from hydrophilous ancestors, or has the converse happened; namely, have the water-lovers, represented by *Eristalis* and *Helophilus*, been degraded so far as their larvæ are concerned to meet their requirements as aquatic insects?

In favour of the first, we may urge that, as a marine vegetation preceded the terrestrial flora, the aquatic Arthropoda are the most ancient. Crustacea are of very great antiquity, and can be traced backwards to the Cambrian rocks.

But if the Crustacea, Insecta, Myriapoda, and Arachnida are indeed all branches of a common stock, it is evident that the water inhabitants and water-breathing Crustacea especially must be regarded as the original stem from which the other terrestrial classes with this branchial respiration have branched off (Fritz Müller).

We may also urge that Libellulæ, Ephemeridæ, and Tipulidæ are found in the remote but geographically speaking less ancient Miocene rocks.

Again, in consequence of the increase of the area of dry ground from the upheaval of the first lands, aquatic forms, through a slow but accumulative variation of secondary organs, such as tracheal tufts, gills, and branchiæ, might usefully assume the aerial forms of air-sacs and respiratory tubes, such as are found in terrestrial insects.

On the other hand, we find as a fact that land-living Coleoptera and Orthoptera are represented in the ancient Coal-measures; and that these are some of the oldest forms of insect-life which the rocks have yet afforded us.*

Our knowledge of the larval stages of Palæozoic and Mesozoic insects is extremely meagre. And indeed amongst the thousands of specimens figured from the great Tertiary insect beds of Oeningen in Switzerland, and Florissant in America, I do not remember a single figured example of a larva either dipterous or hemipterous.

Fürbringer somewhere remarks that the smaller members of a group of animals will probably give the best results in a study of their physiology; that is, such members more usually show primitive types and indications of their ancestry. Again, some biologists have hazarded the idea, that all ancestral relatives of an animal formed groups of small size.

Certain considerations would lead us to the belief that aerial came from aquatic forms; but from the incomplete state of our knowledge caused by want of material, generalization at present would appear to be very unsafe.

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* A few others in the underlying Devonian rocks are known, and one (*Palæoblattina*, Brongniart) has been recognised in France.

Closing these somewhat desultory remarks, we will narrow our considerations to the economy of the Aquatic Syrphidæ.

In primæval times we may suppose that many forces of nature, meteorological and other, were on a scale greater than we see now. We may imagine carcases of animals floating down the mighty rivers which drained the swamps around. Such carcases would doubtless be tenanted by millions of larvæ of Muscidæ and flesh-eating flies. Of the larvæ which became submerged and finally got stranded on the muddy shores, we may further suppose that those having the best developed air-trunks would preferentially survive, and that, on utilitarian principles, there would be a tendency to develop caudal spiracles, which would the better enable them to breathe under their new condition. Simultaneously certain spiracles would be suppressed as useless in the new environment, and a type of an aquatic larva would appear.

The morphologist will see that such speculations bristle with difficulties, and that they cannot be thought to explain much more than possible sequences.

Before the imago is formed in the nymph, nearly all the internal organs of the larva disintegrate into a whitish magma, out of which the members of the new imago are elaborated. The legs, viscera, and tracheæ of the one stage of the insect therefore are not those of the other.

Unless we can devise some scheme like that of inherited instinct, or conceive something analogous to the "imaginal discs" of Weismann, there seems to be no provision for the perpetuation of characters once acquired in the larva, and so enabling it to pass them on to the adult and to her ova.

Instinct, though a blind guide to animals, is yet a very sure one, in their default of intelligence, and they long resist the influences which tend to break through the ordinary characters of species. It operates in fact against the powers of adaptation.

Beneficial variation can scarcely arise without some anticipatory purpose to control the steps, for the very term selection seems to presuppose choice from some kind of intelligence, except to those minds which would rather wrestle with metaphysics and the subtleties of abstract reason.

Few will deny to the higher animals some results from their experience, and an intelligence confined within small limits. Thus birds soon find out the meanings of snares and traps, and fish learn the deceit of the angler's fly of feathers. Experience in the lower animals is mainly, however, exercised in matters of security from danger, provision of food, and modes for the perpetuation of their species. Beyond these, experience passes into the quasi-automatism called instinct, in which reason is supposed to have no part.

In a somewhat similar way persistence of character and resistance to change may be instanced in the vegetable world. As a familiar example we may note the fact that trees like *Eucalyptus*, and plants like *Berberis Darwinii*, and species of *Erica* from the Cape of Good Hope, have not yet been able to change their seasonal characters. Transplanted from southern to northern latitudes for more than one hundred years ago, many plants have not succeeded in altering their seasons of flowering and fruiting. The inversion of summer and winter thus causes many such plants to succumb to our winters, in which they still continue their original seasonal times of flowering. The Patagonian winter is more severe than our own, yet examples of the above *Berberis*, which is a native of the high latitudes of South America, are often killed with us whilst prematurely preparing their flowering buds.*

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* May not the observation of the fact, that Australian vines, transplanted to the Rhine-terraced slopes, can survive the attacks of the dreaded *Phylloxera* be accounted for by the circumstance that when this aphis is in full activity, the sap of the Australian vine is seasonally at its lowest ebb? It thus but little feels the insect's attack, and in a measure the *Phylloxera* is starved out.

# VI. DISTRIBUTION.

## (*a*.) GEOGRAPHICAL.

Baron von Osten Sacken remarks that, with the exception of the honey-bee and the silkworm-moth, no insect can show such a historical record as *Eristalis tenax*. Its wide distribution in connection with the wanderings of man will be again alluded to.

Its comparatively late appearance in Australia and in North America may be accounted for, partly from the tenacity of life as shown in the fly, partly from its resistance to frost and low temperature, and lastly from the habit of hiding in crevices, as shown by the ovigerous female during hybernation. The rapid passages of our shipping over the ocean, and the quick transit of our merchandise are conditions more favourable for the spread of insect-life than the agency of winds. Currents of air seem unsuitable for transporting a heavy fly like *Eristalis* over a thousand miles of ocean and more, but the flies in fodder and the larvæ in water on ship-board can easily be carried.

The laws, however, which govern the distribution of species are as yet but little known.

*Eristalis tenax* has been long known both in China and Japan. Baron von Osten Sacken thinks that the insect migrated eastwards from the former country.

The species does not appear to be indigenous to North America, but to be a late introduction. Its first recorded appearance on the Western Continent was observed in 1870, since which time the species has been seen there "by hundreds," and elsewhere, as in Canada, California, and Mexico, and indeed throughout the United States; where it is also accompanied by its natural parasite, *Tropidopria conica*, Tab.

Its presence in the stagnant waters and the drains at

Ashburton, in New Zealand, was testified to by Mr. W. W. Smith in 1890. He also found the larvæ in hundreds thriving in "the atrocious stuff" standing in the barrels of a wool-scouring works some short distance from that town.*

When once the insect has been introduced into a country it spreads with rapidity. Vast plains and mountain ridges check for a time its invasion, but they do not stop the march of the insect.

In a similar manner *Helophilus* has been introduced into North America, and taken plentifully in the salt-water canals of Salem Harbour, United States.

*Eristalis tenax* occurs over the greater part of the continent of Europe. The larvæ swarm in many sewers of Vienna. The fly is known in Lapland, and in Iceland, for Dr. F. Walker sent me a single specimen of *Eristalis arbustorum*, captured by him at Reykjavik.

The common occurrence of *Eristalis* in some years has been before noted. Mr. C. Horne, in the summer of 1869, found the winged flies, largely mixed with other Syrphidæ, swarming on Ramsgate pier. They were thought, at the time, to have been driven by winds across the Channel.

Mr. F. Smith, at another time, met with numerous dead bodies of Syrphidæ fringing the surf at Bournemouth, and similar swarms have been recorded on the shores of the Isle of Wight. The vicinity of hop-gardens, with their constantly attendant pest of *Phorodon humuli*, would partly explain this abundance of Syrphidæ, the larvæ of which consume many millions of the hop-aphis. These form, indeed, their principal food.

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* Ent. Mon. Mag. 1890, p. 240; and 1892, vol. iii. p. 110.

## (*b.*) GEOLOGICAL.

Diptera are of great geological antiquity. They appear simultaneously with Hemiptera; and certainly as low down in the rocks as the Lias. It is probable that in the days when much of the earth's surface was more or less of a swampy and brackish nature aquatic insects in the order of time would precede terrestrial insects.

Even now several species of gnat and beetle are known to live in salt and brackish water, and there they find their food amidst the seaweeds and decaying matter. This habit makes more probable the supposition that the first insects were, like the ancient Neuroptera of the coal-measures, inhabitants of water; and possibly, like them, they possessed gill-like respiratory organs, and were predatory in habit.

"The first announcement of the discovery of fossil insects in America was that by Hartt, of the finding of four kinds of insect-wings in the 'Fern Ledges' of the Little River Group of the Devonian (Erian) strata at St. John, New Brunswick, in 1862 ('Canadian Naturalist,' new series, vol. iii. 1867, p. 205). Insects had previously been found in the Carboniferous strata of Europe, and have since been traced back to the Silurian of France (*Palæoblattina*, Brongniart)."*

It is remarkable how few larval forms of insects have been preserved in ancient strata. There is no assignable reason why they should be absent on account of their fragility, for at Florissant, Dr. S. H. Scudder has shown thousands of insects so well preserved, that impressions are very distinct of their wing-neuration, and this sufficiently to group the species into genera not greatly differing from those of recent times.

The Rev. R. B. Brodie and Prof. Westwood, some years ago, described the remains of several gnats entombed in the Purbeck Beds of Dorsetshire, and in those of the Vale of Wardour. From the last place he noted also what appeared to him to be the *larva* of some dipterous fly.

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* From the 'Zoological Magazine,' June, 1895, p. 275.

Prof. Rupert Jones has very kindly put me in possession of the following extract from Dr. Félix Bernard's 'Eléments de Paléontologie.' As regards Diptera he says (part i. 1893, p. 391):—"Les Diptères fossiles sont moins nombreux que les Coléoptères, mais comme eux ils appartiennent à tous les groupes de la faune actuelle. Beaucoup nous sont parvenus dans un état remarquable de conversion. Les plus anciens datent du Lias inférieur d'Angleterre (*Asilus, Chironomus*). On en trouve quelques-uns dans le Purbeckin et à Solenhofen. Les familles les plus abondantes du Tertiaire sont les Syrphidés et les Bibronidés et surtout les Tipulidés qui sont extrêmement abondants en certains points à Aix, à Florissant, et dans l'Ambre."

The sequence of insect-life on our planet will long engage the interest of biologists. Discoveries here will help much to illustrate the development of new and complex forms out of the more simple, and lift us out of some of the present conditions of speculation and more or less guess-work of Evolution.

It is doubtful whether *Eristalis* occurs in the Tertiary or other rocks of America. It is true that Dr. H. S. Scudder briefly describes the remains of an insect embedded in the Oligocene sedimentary rocks of the White Valley, Colorado, which he names *Eristalis lapideus.* Nevertheless he expresses some doubt as to its true family connection. Again he notes, in the same locality, the occurrence of a large *Milesia,* one of the Syrphidæ.*

If *Eristalis* only follows the tracks of man, as Baron von Osten Sacken appears to think, its appearance in ancient America will be all the more unlikely.

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* See 'Tertiary Insects of North America,' by S. H. Scudder, 1890, pp. 558 *et seq.*, pt. 5, figs. 48 and 94; also Prof. Heer on *Syrphus infumatus* in the strata at Radoboj, Croatia.

Germar noted the occurrence of *Helophilus primarius* in fossiliferous deposits near Bonn, in Rhenish Prussia.

## VII. MYTHS

### Connected with Eristalis.

Baron von Osten Sacken, of Heidelberg, has published a very curious and exhaustive essay on the wide-spread and extraordinary superstitions connected with what has been called the spontaneous production, and the artificial breeding of bees from the carcases of oxen. This superstition is believed partly to have originated from the mimicking resemblance of the adult *Eristalis tenax* to the drone of the honey-bee.

Notwithstanding grave difficulties, such as that *Bugonia* (a word equivalent to the Latin "taurigines apes") are asserted to be honey-producers and comb-constructors, evidence seems strong, that the oxen-born bees of Greek and Roman authors can be no other than the flies of *Eristalis tenax*.

Myth, and stories involving a love of the marvellous, so often woven into the charms of poetry, doubtless have much to answer for in spreading many false notions of things over the world. As regards the above belief of bee-breeding, we may remark that Egypt, China, Japan, and the greater part of ancient civilized Europe have been all more or less affected by this strange idea. In the first place we have the picturesque old Hebrew riddle:—[*]

"Out of the eater came forth meat;
Out of the strong came forth sweetness."

Notwithstanding the solution given by the propounder of this riddle, the enigma continues an enigma to the present day, for the express mention of bees and honeycombs seems to preclude the idea that a fly like *Eristalis*, which makes neither honey nor comb, can have been the insect observed.

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[*] Judges xiv. 14.

Again, the fact that bees do not build in carcases, for "they are clean animals," leaves us in a dilemma; unless we accept Bochart's idea, which surely begs the question, that the ribs of a bleached skeleton might possibly form a framework for the suspension of the combs of the honey-bee.

In old Greek story, bees are said to have once used the empty skull of a malefactor for their hive, but this appropriation was considered to be then a portent so remarkable, that it became a subject of appeal to the oracle for its solution.

We may say that modern European bees do not build in carcases, and that they are intolerant of bad odours.

The conditions of Samson's riddle have exercised many minds. Several insects other than *Eristalis* show resemblances to bees or wasps. Thus we have *Œstrus*, *Crabro*, *Helophilus*, and *Volucella;* but as none of these flies make honey, they may be dismissed from consideration.

Baron von Osten Sacken* records that *Eristalis tenax* oviposits on carcases in a state of far advanced decomposition, "in which the larvæ thrive"; and the observation so far corresponds to the tradition of the oxen-born bee.† But in another place he notes, "It is very rare now to come across a carcase and to see *E. tenax* hovering about it. The only instance I have found in the literature consulted by me concerns another species of *Eristalis*—*E. anthophorinus*, Zett.,—and that instance occurred in Lapland"; where "a small swarm round the carcase of a sheep was noted."

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* *Bugonia, l.c.*, p. 9; idem, p. 32.

† 'On Oxen-born Bees of the Ancients, *Bugonia*,' by Baron von Osten Sacken. Heidelberg, 1894.

But such an observation does not necessarily prove that the hovering insects were bred there, or were ovipositing on the dead animal.

Ælianus, who lived in the second century, claims as one of the useful qualities of oxen, "that their remains are capable of originating bees, the most laborious of insects, which provide men with honey," &c.

Many Greek and Latin authors have written on *Bugonia*,* fully believing the mythic tale relating to Aristæus. In this manner Pliny, Varro, Ovid, and others have helped to spread this extraordinary myth. The purport of the story, as told by the last-named poet, is, that Aristæus, who first taught men to plough and to keep bees, was appealed to, and supplicated for help by certain shepherds who had lost all their swarms of bees. He, instructed by his celestial mother, told them that they might regain their riches from a slaughtered bullock, if they raised suitable altars to the gods, observed certain ceremonies, and treated the carcase in a particularly described manner, when swarms of oxen-born bees would enable them to replenish their stores.

It is remarkable that for so long a time the constant failure of this process to produce honey-bees, did not shake the confidence of the vulgar. Hard it is to kill credulity.

Virgil, in his 'Georgics,' has the lines—

> . . . "De putri viscere passim
> Florilegæ nascuntur apes." . . .

Nearer to modern times we find that Aldrovandus, Melancthon, our English Dr. Moufet, and other writers, countenanced this notion, and even Shakespeare seems to have leant to it—

> "'Tis seldom when the bee doth leave her combs
> In the dead carrion."—*King Henry IV.*, pt. 2.

On the other hand, the biologists Swammerdam,

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* From βοῦς, an ox; γονή, generation.

Vallisneri, and Réaumur, in 1750, discountenanced the idea of such a fanciful and spontaneous generation.

As might have been expected, Baron von Osten Sacken's ingenious and probable theory, in connecting *Bugonia* with *Eristalis*, has met with criticisms, which he answers at the end of his interesting and learned essay, the perusal of which will well repay those who take interest in the literature of this subject.

The author of this more recent treatise appears to be in some hesitation as to the fact of oviposition and habitat of *Eristalis* in carcases. I do not gather from his text that he has seen such oviposition, or identified the larva feeding in such animal masses. Negative evidence, however, can prove nothing, and it may be hazardous to differ from such an experienced dipterologist; but I may note that, although I have taken *Eristalis* larvæ in many noisome situations, I have never met with them in any carcase. Foul water with carcases in it may suit the economy of *Eristalis*, but its whole physiological construction points to an aquatic and not to a carnivorous habit.

Baron von Osten Sacken rather leans to the conclusion that the larva of *Eristalis* occasionally develops within the intestines of man. At least he says that "there are a dozen well-authenticated instances of such."

Dr. Balthasar Wagner stated that, in 1870, from three to five larvæ were voided alive from a patient, from one of which the adult of *Eristalis arbustorum* was bred. It was suggested that these larvæ may have been in bad water drunk by the patient. This to us appears very improbable, namely, that a larva, so differently constituted as *Eristalis* and *Gastrophilus* or *Œstrus*, should be able to resist the gastric secretions, and thrive at the temperature of human viscera, in the conditions of which a high oxygenation would appear to be impossible.

# VIII. HOMOLOGIES

## Shown by Eristalis to other Aquatic Larvæ.

A few sentences here may be allowed in connection with certain nearly allied Syrphidæ and Diptera having larvæ of aquatic habits. As a preliminary it may be remarked that the tracheæ of two-winged flies are developed very much after a common type. For my purpose I select only a single species of a few genera for illustration.

The long respiratory tubes of aquatic dipterous larvæ may be regarded as only elongated spiracles. The stomata of such adult flies rarely exceed six on each side, whilst the larvæ have fewer, and these are mostly placed on the last abdominal segment, near to the anus.

### *Helophilus pendulus*, Linn.

The larva has seven pairs of pseudopodia. Its respiratory system is almost identical with *Eristalis*, and, like it, it shows two spiracles at the end of a telescopic tail. The larvæ live in muddy pools, and there these long-tailed creatures are not uncommon. The imago is black; head yellow in front, with a black stripe; thorax with four yellow stripes; wings greyish, with yellow halteres; abdomen semitransparent, and barred with black.

### *Volucella pellucens.*

The internal anatomy of this nearly-allied *Syrphus* has much in common with that of *Eristalis*, both in the larval and the adult stages. As the grubs of *Volucellæ* prey on the larvæ of bees and wasps, and are not aquatic, suitable alterations are made in the adaptation of their respiratory organs; and they illustrate the almost indefinite powers shown by larval Diptera, in elaborating and supporting parts not concerned in the welfare of the adult creatures.

The grubs are footless, but they show small *false* feet with minute hooks; the long spiracles at the tail-end are absent. The larvæ are blind, and apparently bereft of all senses, except touch. The puparium is very like that of *Eristalis*, and it develops outward cornua. The case is provided with a hinged operculum, which remains attached after the fly has escaped. Some have described the mode in which the fracture is made in the puparium, through the expansion of air or fluid below, and completely effected by the struggles of the pupa within, at the time of exclusion. The imagos are handsome and excitable insects, strong on the wing, and practised hoverers over flowers. They fearlessly enter the hives of bees and wasps, and there they oviposit. The larvæ feed on the bee-grubs as they issue from the ova, after they have become half-fed.

*Volucella pellucens* is remarkable for the large air-loculi developed in the adult. These appear as two great transparent bladder-like chambers, one on each side of the abdominal line. Internally the abdomen is divided, as in *Eristalis*, by a distinct septum. There are two lateral tracheal trunks, which run for a certain space parallel to this septum. At the base of the first abdominal ring they furcate, one branch running down the right side, and the other down the left. Other furcations communicate through branches with the abdominal spiracles. As in *Eristalis tenax*, these great air-pouches are overspread with a delicate greyish intima; thus showing that the respiration of the two allied genera is practically the same.

I regret that I have been unable to trace, even with the assistance of a one-eighth objective, a distinct continuous vessel uniting these capillaries. If such a vessel or vessels could be seen to anastomose with vessels of the circulatory system, the analogy of lung-pouches would seem to be the more obvious.

The epistoma of *Volucella pellucens* is swollen into a horny protuberance, which entirely covers the trophi.

### *Corethra plumicornis*, Meigen.

The larva of this well-known *Culex* is chiefly remarkable for the four dark reniform bodies, which show conspicuously within its transparent and almost glass-like body. There are two black kidney-shaped bodies situated in the thorax, and two smaller ones in the caudal region. Under sufficient magnifying power these black bodies, from which air can be expressed, and are thus proved to be air-pouches, are seen to be surrounded with a muscular coat, which is covered with beautiful striations, exactly as we find in the great air-trunks of *Eristalis*. In addition to this, their surfaces are dotted with seventy or more dark convex glandular bodies, which Newport showed to cover partial perforations, through which he conceived the circulating fluids of the larva might be most "freely aerated, just as we find in the minute cells on the lungs of vertebrates." The kidney-shaped sacs are clearly respiratory; but I have failed satisfactorily to trace any connection between them and the more usual long transparent tracheal trunks; though doubtless they will be found at some time to anastomose with them. The larvæ also employ these membranous sacs (which appear black only through the dispersion of light on their surfaces) as buoys to alter their gravity in water, just as we see to be the case in *Eristalis*.

### *Stratiomys chamæleon*, De Geer.

Larva aquatic, with long jointed caudal spiracles. Often floats with its head downwards. Swims and progresses by a kind of figure of 8 movement. Entangles a bubble of air, with which it descends to the bottom of pools. The imago feeds on the flowers of aquatic plants. (Walker, Ins. Brit. vol. i. p. 15.)

The larva of this interesting insect was described long ago by Swammerdam,* by Réaumur, and more recently by Prof. E. Blanchard.†

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* 'Biblia Naturæ,' pp. 649 *et seq*. pl. 39–42.

† 'Metamorph. des Insectes.' E. Blanchard. 1868.

The head is small, and furnished with two recurved hooks, which act as mandibles, or else represent them. The caudal respiratory tube is long and jointed; it terminates with a circlet of setæ at the end of the single caudal spiracle. The larva floats on the surface of the water. The metamorphosis is incomplete, and the chrysalis may be seen enclosed within the membrane of the puparium, just as in *Eristalis*. No apparent outward change is made in the larva as it approaches its metamorphosis, but the body forms a constriction in its midst, "et on trouve une nymphe, la peau de la larve est devenue une coque, un bateau pour la mouche qui viendra à éclore."

### *Dicranota bimaculata.*

The anatomy of this Tipulid has been well worked out and illustrated by Prof. L. C. Miall.* During its larval stage it buries itself in mud and sand at the bottoms of ponds and slow streams. It generally avoids daylight, and it swims by a head-and-tail looping action, like many other water-forms of insects.

The larvæ breathe by a complex tracheal system, the air entering by two stomata placed at the ends of two short caudal eminences leading to two parallel air-trunks. The animal is capable of protruding these stomata above the surface of the water. The larva possesses five pairs of pseudopodia, which are similar to those seen in *Eristalis*. Their chief food is the little worm *Tubifex rivulosum* and certain Gregorinæ. Unlike the larvæ of most Diptera, the head is distinct; and there are crushing teeth fixed at the entrance to the pharynx. Similar as is the internal larval anatomy of *Dicranota*, the imago is very dissimilar in form to that of *Eristalis tenax*.

Before closing this short list of Diptera which have larvæ aquatic in habit, and show affinities with *Eristalis*,

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* 'Trans. Ent. Soc. London,' 1893, pp. 285. Three plates.

I may mention the dipterous Ptychoptera. They have caudal retractile respiratory tubes, within which two convoluted tracheæ run to the end. They have also two side appendages before the insertion of the last joint of the same, the use of which is unknown. The larvæ have indications of eyes, and the pupæ are each furnished with a respiratory tube attached to the head, and, which is remarkable, it attains to more than twice the length of the body of the creature itself.

## IX. GENERAL REMARKS.

In conclusion we may say that, though a well-known physiologist has affirmed that all argument from design has utterly broken down,* there are minds of high capacity and grasp who see no contradiction between processes of evolution and purposive phenomena.

If we exclude fortuity, we must adopt M. Künckel d'Herculais's opinion, that we have to do with "la grande loi de l'adaptation par laquelle on insiste de nos jours avec tant de raison."

What is called the explanation of a fact is nothing more than assigning its cause, that is, giving the preceding set of facts out of which it arose. Aristotle was a firm believer in the adaptation of organs to definite ends, and he points out that "the saw was made for sawing and not sawing for the saw." Nature designs or contrives.

The ancient intelligent Greek worshipped the "Upholder," the Unknown, the Unconditioned; and the Deist of the last century accepted such an argument from Design and fitness through the establishment of law.

But Richard Proctor felt that the overwhelming sense of the vastness of things almost tempts some to shut their eyes, and to content themselves with their own horizon; and so they would attempt to set a limit to space, out of very despair.

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* Haeckel, 'Evolution of Man,' pp. 115–163.

For those who regard the question of evolution with uneasiness, we may quote Mr. A. J. Balfour's words speaking as a philosopher:—"The establishment or the contrary, cannot invalidate convictions of the existence of the Divine Spirit, who is the Ground of all being, and the Source of all change." Again, "The argument from Design is *one of many* arguments in favour of Theism; yet it cannot prove the existence of God, for you assume a phenomenal Universe, which to us alone makes proof possible." Thus "the argument from design rests on the world as known" to us.*

Again, as the Duke of Argyll states the case:—"No possible amount of discovery concerning physical causes of natural phenomena can affect the argument, that the combination and co-ordination of the causes which produce the apparent effects of purpose, are really and truly what they seem to be, *viz.*, the work of Mind and Will." †

* A. J. Balfour, 'Foundations of Belief,' p. 296.

† See 'Nature' for Oct. 21st, 1881.

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## PLATE I.

Fig. 1.—Imago of the oviparous *Eristalis tenax*, magnified nearly three diameters. *a*. Head, showing three ocelli and the antennæ. *b*. Fringed alula, partially encased by the wing. *s*. Scutellum below the metathorax. *o*. The five-jointed ovipositor, as naturally exserted just before the act of oviposition. The peculiar venation of the wings may be noted.

Fig. 2.—Femur, tibia, and tarsus of the fore leg of the same insect.

Fig. 3.—Terminal joint and pygofer of the male. Below, two hairy parapalpi are visible, each tipped with black hairs. On one side is seen part of the hypophallus.

Fig. 4.—Halter or poiser, which is placed under the alula. *h*. The head or capitulum. *s*. The scape. Also see Plate IV., fig. 5.

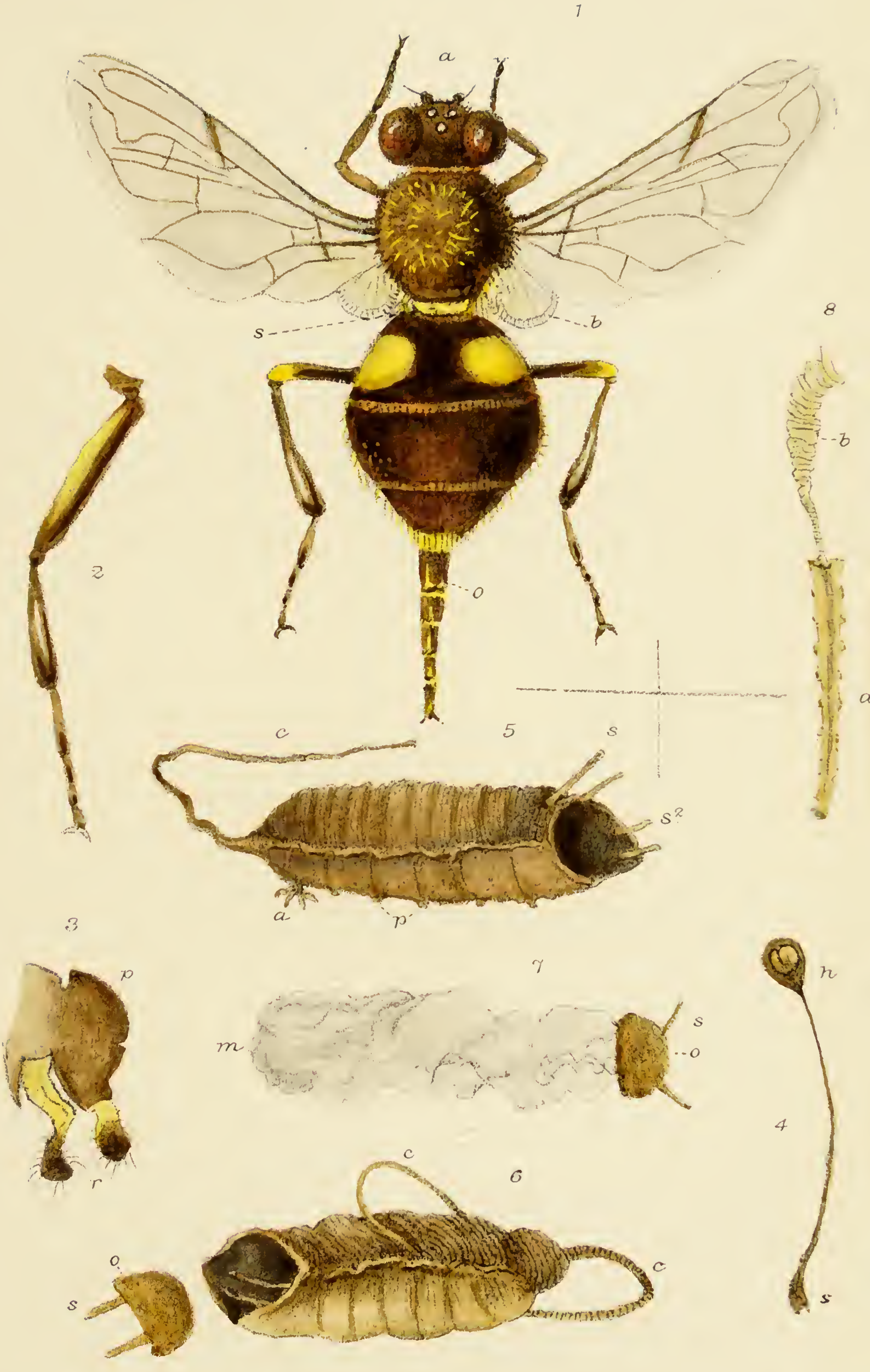
Fig. 5.—The rigid and dry puparium of *Eristalis arbustorum*. *a*. Anus, with the dry remains of the surrounding laminæ of the larvæ. *p*. Remains of two of the pseudopodia. *s*. The thoracic stigmatic cornua. $s_2$. The operculum, with cornua. *c*. The dry sheath of the caudal tracheæ.

Fig. 6.—Empty puparium, after the escape of the imago. *o*. Operculum detached from its case; it has burst along the sutures. The upper cornua are attached to the puparium, but the lower (*s*) are retained. Sometimes the operculum is dragged partially into the case by the pupa, before the imago frees itself from its membrane.

Fig. 7.—*m*. The soaked and unravelled pellet, composed of the membrane which invested the imago. *o*. Operculum, with the cornua.

Fig. 8.—*a*. One of the puparial cornua, partly torn from the interior of an immature puparium, showing at *b* part of the tracheal tube, which traverses the cornua to the tip, thus imitating the stigmatic cornua of the gnat. This trachea is suppressed in the perfect fly.

# PLATE I.



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# PLATE II.

Fig. 1.—A nearly full-fed larva of *Eristalis tenax*, dorsal aspect. *a*. Front, with its tactile protuberances. *b*. Muscular bundles, serving to retractation of the head. *c*. Cornua, which can be partly protruded. *d*. Pharynx behind the mouth, with its muscles and mandibular horny teeth. *e*. Part of the œsophagus, with epithelial scales. *t*, *t*. Great tracheal trunks. $t^2$, $t^2$. Fine tracheal tufts near the false feet, and tubes from main trunk. *h*. Dark space, with dorsal vessel and folds of the intestinal tubes. *f*. White sebaceous mass, or epiploon, composed of sacs filled with fat oil. *m*, *m*. Red malpighian vessels, ascribed by some to the biliary system. $j, j_2, j_3$. Three partially-extended sliding joints of the respiratory tube, formed of elastic tissue attached to the two tracheal tubes running parallel to each other, till they end in the setose spiracle at *s*.

Fig. 2.—Ventral view of a young larva of *Eristalis arbustorum*. *m*. Vessels filled with a red liquid, similar to the blood seen in the larvæ of some gnats. These tubes probably have some renal function. Their fine ramifications permeate the greater part of the body. *i*. Investing muscular integument. *p*. Chyle-stomach, and part of the proximal intestine. *t*. Tracheal sacs, and part of the intestinal alimentary tubes. A dark-coloured stellate body is figured; it was only observed in one specimen. The purport of this body is obscure. *s*. Spiracle, with the termination of the tubes as they appear when fully retracted into the young individual. The other numerical figures represent organs as before.

Fig. 3.—Imago of *Eristalis arbustorum*, drawn from a finely-coloured Irish specimen.

Fig. 4.—Antennæ of the male insect, with the minute puncture on the third joint.

Fig. 5.—Vertical section of the head of *E. tenax*, with the basal plate removed to show the internal parts from behind, forwards. *j*. Outer integument of the cornea, &c. *c*. Section through the cornea, exposing the eye-cones. *p*. The red spongy mass of pigment originally attached to the plexus of retinal nerves. *v*. Vacuity caused by the action of the section knife, and separating it from the choroid. *o*. Neural masses

connected with the ocelli and the antennæ. *n.* Irregular ganglionic ringed mass, surrounding the neck and its communications with the thorax. *œ.* Channel of the œsophagus, seen in section. *r.* Attachment of the proboscis, in section. A more magnified and complete section through the eye of *Eristalis* may be seen in Plate VI.

Fig. 6.—Exterior and front view of the head of *Eristalis tenax,* showing the two antennæ, each rising from under the hooded process. *c.* Cornea, with its thousand and more lenses. *d.* Clypeus, with its pilose exterior. *ep.* Epistoma, or cover to the proboscis, part of which last may be seen below the notch.

Figs. 5 and 6 are amplified about six diameters.

Fig. 3 is amplified about three diameters.

PLATE II.

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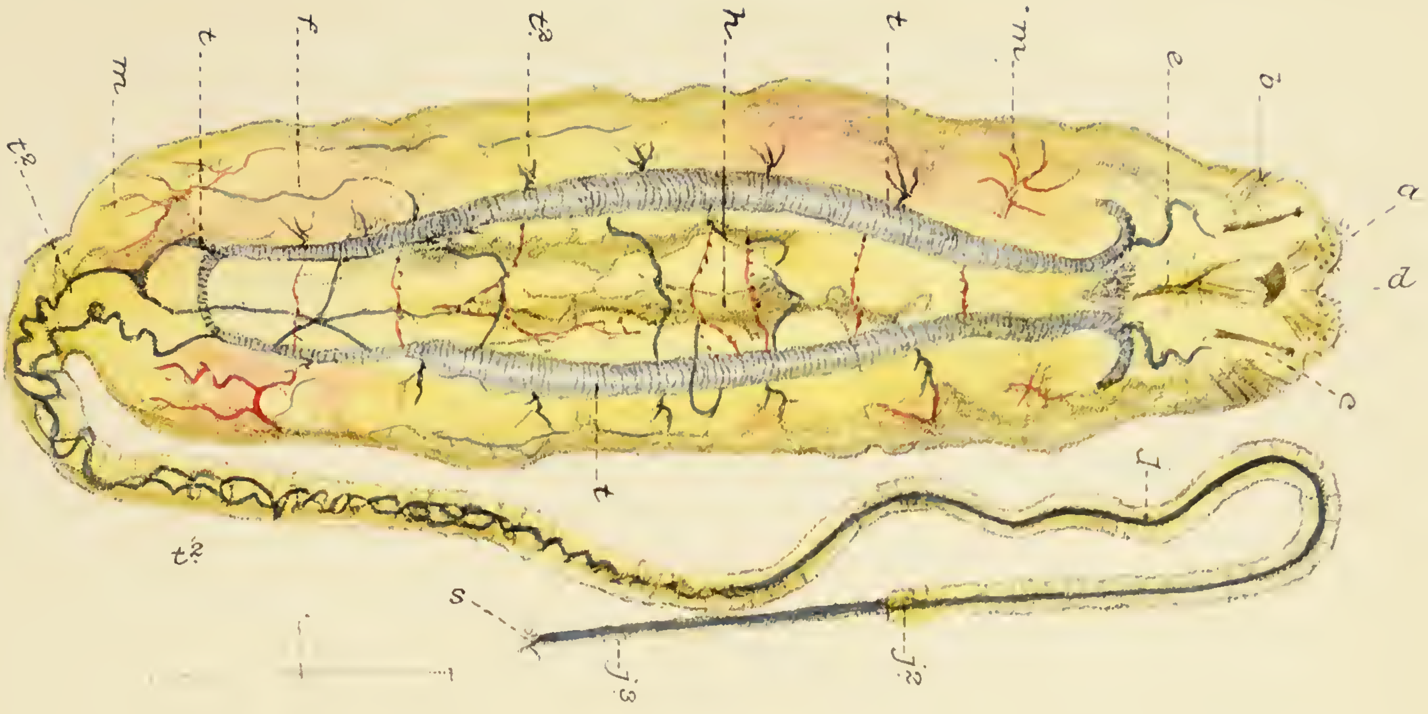

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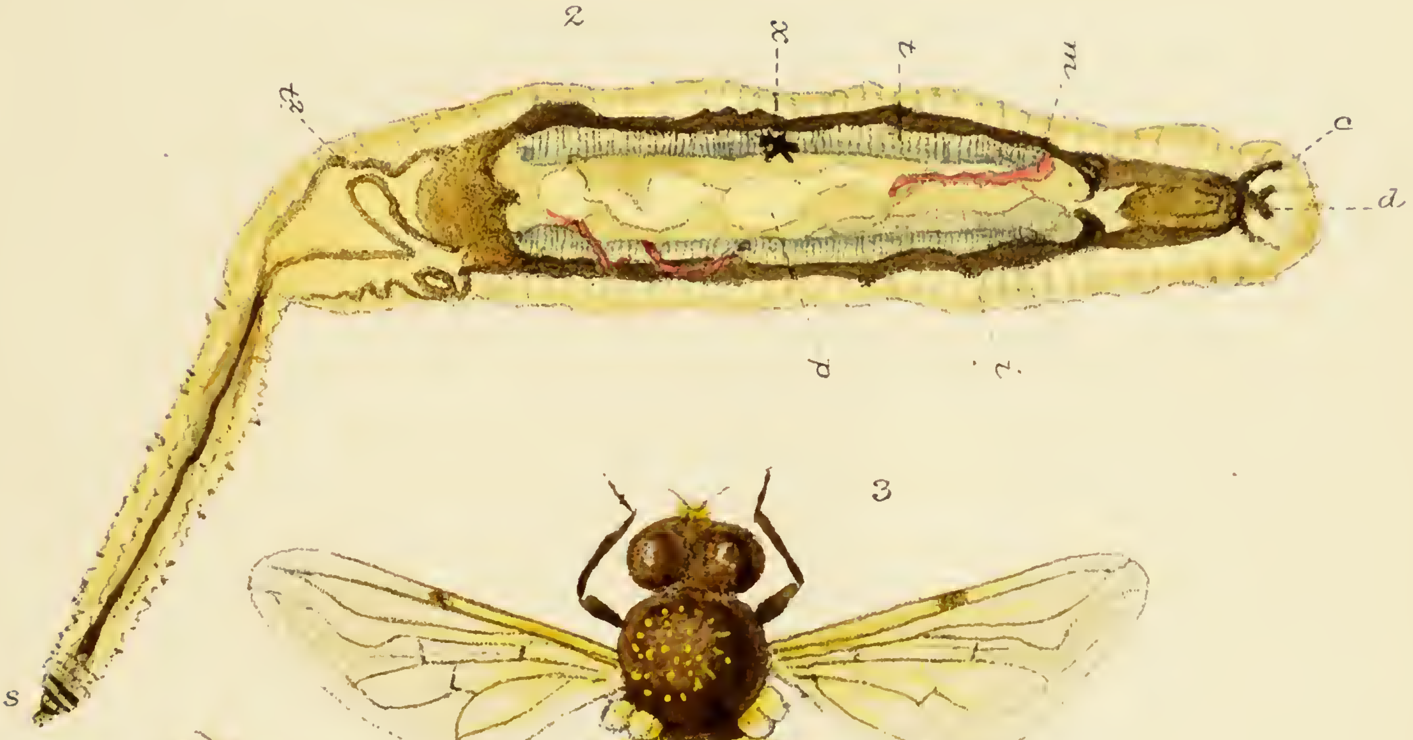

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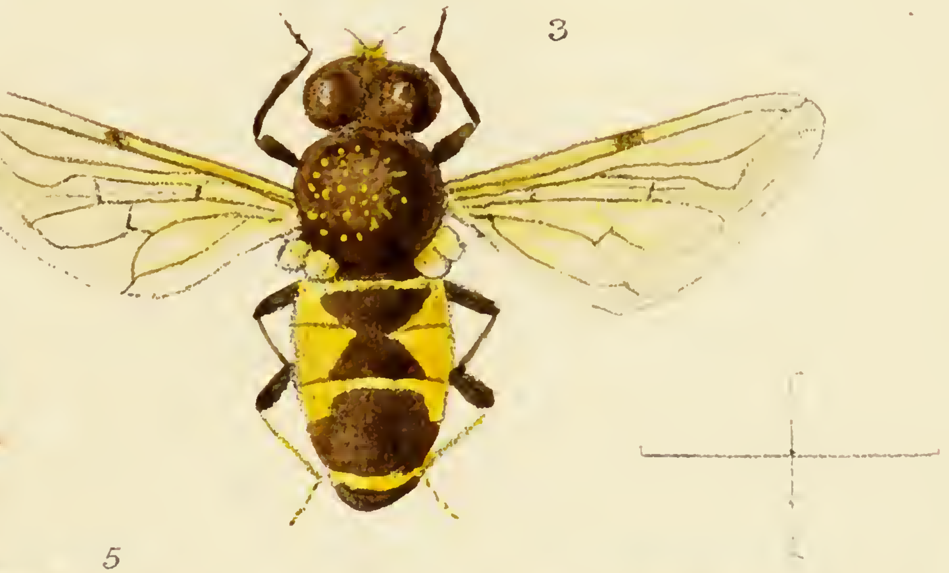

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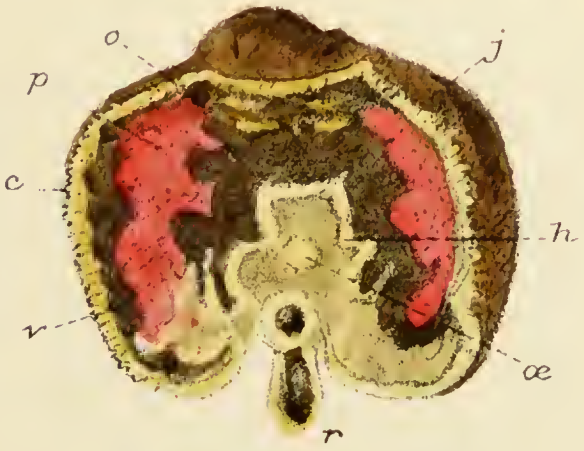

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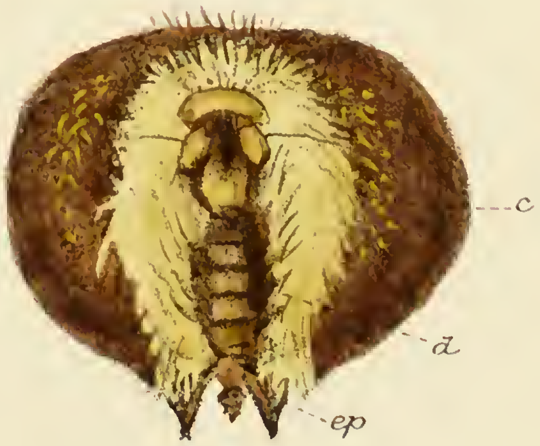

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## PLATE III.

Fig. 1.—Anterior part of the head protruded from the first segment of the larva of *Eristalis tenax*. *a*. The stigmatic horn retracted within the integument. *b*. The labrum, studded with tactile papillæ. *c*. The upper mandibular tooth, at the entrance to the œsophagus, drawn back towards the pharynx. *d*. Processes of dental attachment *e*. Lower mandibular process.

Fig. 2.—The same parts from another specimen, but more magnified. Ventral aspect. *a*. Pseudopodia, with their hooklets. *p*. The papillæ, which cover the whole surface, and which act as tactile organs. *c*. The upper mandibular tooth thrust forward. *e*. The lower mandible, with its trident edge. *d*. The muscle controlling the tooth, which, by a grinding motion with the upper tooth, causes a comminution of the solid matter passing between them.

Fig. 3.—Part of the stigmatic horn, with its apex protruded above the surface of the integument. *a*. Imperforate apex. *b*. Part of the cuticle.

Fig. 4.—Pharynx of the larva of *Eristalis tenax* (objective, $\frac{2}{3}$ inch). *œ*. Entrance from the mouth. *e*. Lower mandibular tooth, as before. *d*. Inner walls of the viscus thrown into corrugation. *g*. Part of the œsophagus, the walls of which are dotted with epithelial scales, showing the insertions of the salivary ducts.

Fig. 5.—Part of the caudal respiratory tube, showing that although two tracheal tubes run parallel for a great length that they do not kink or their walls collapse if they be tied into a knot by the larva. The tough transparent cuticle appears to coalesce at the knot, but the walls do not fuse together. The drawing represents the simplest knot made by the larva.

Fig. 6.—One of the pseudopodia thrust out from the integument. The hooks vary in size, are more or less recurved, and can be withdrawn into the body.

Fig. 7.—Portion of the tactile head-protuberances, much magnified. The greater part of the integument of the larva is covered by minute hooklets.

Fig. 8.—Anal opening, surrounded by soft flabellæ. Each

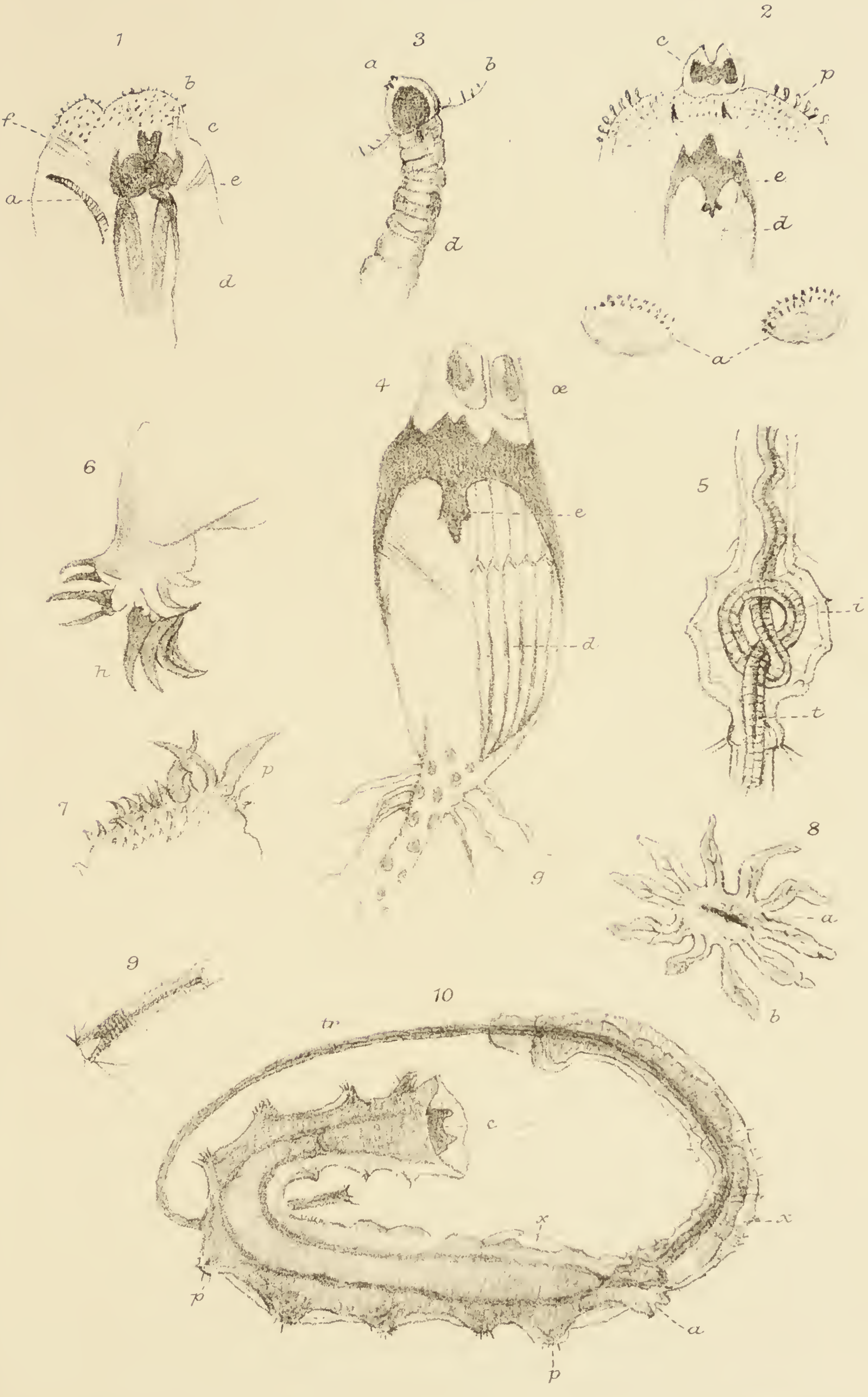
leaflet is supplied with a minute branched vessel, possibly having a renal function.

Fig. 9.—The extreme end of the respiratory tube; the fine tracheæ open into a funnel surrounded with stiff bristles. The repulsion of water from the cilia allows an open passage of air through the stoma or spiracle.

Fig. 10.—The larva of *Eristalis arbustorum*, just before it changes into the puparium. The anterior part is retracted. The greater part of the body consists of fat masses, concealing the viscera. The inner part of the integument has already begun to disengage itself from the outer sheath; this becomes the puparium. *p.* The pseudopodia become more marked before the animal assumes the more ovoid and rigid shape. *x, x.* Places where the integument shows itself like a moult. *a.* The anus. *tr.* Tracheæ.

Amplification.—Figs. 1 to 5, thirty diam. Figs. 6 to 8, forty diam.

PLATE III.



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## PLATE IV.

Fig. 1.—Vertical section through the thorax of the imago of *Eristalis tenax*. *a*. The alula. *b, b*. Fascicles of muscles (musculi metanoti depressores?), which approximate the upper and lower thoracic plates. *c, c*. Muscles, ending in tendons running to the neck (rotatores capitis). *f, f*. Great depressor muscles of the wings; they occupy the chief part of the thoracic cavity. *h, h*. Halteres, in close proximity to (*p, p*) pulmonary chambers. *s, s*. Thoracic spiracles. *tr*. Muscular bundles, leading to the trochanters. *w, w*. Attachments to the wing nervures. *v*. Part of the alimentary canal, seen in section.

Fig. 2.—Another section through the thorax, showing the cavities of the great air-chambers lined with membrane, and overspread with delicate tracheæ after removal of the muscles. *r*. The inner walls of the great bulla. The plate which unites this part of the thorax to the head has been removed. *p, p*. Lateral empty pouches, with membranous walls. *t, t*. Horny rings, which show shining tympanic membranes from within. *s*. Muscle and part of the thoracic septum, seen edgeways. The viscera and fatty tissue have been removed. *w, w*. Part of the wings.

Fig. 3.—First abdominal ring, seen in section, near the part which articulates with the thorax. *f*. Alimentary tube, seen in section. *r, r*. White fimbriated masses of muscles, which expand or contract the abdominal rings (musculi recti, dorsal and ventral). *s*. Abdominal septum, dividing the cavity into two chambers.

See also Plate VIII., fig. 3, *f*.

Fig. 4.—Antennæ of the imago of *E. tenax*, showing part of the hood from under which they spring.

Fig. 5.—Region under the wing of the imago, showing one of the halteres *in situ*. *a*. Part of an alula. *e*. Capitulum, with its bladder-like head. *st*. The style, leading to (*sc*.) the scape, with its corrugated wall. *sp*. The great spiracle, with its fimbriated entrance near to the hollow chamber above.

Fig. 6.—Foot of imago, showing at *a*, two claws; at *b*, two fringed and punctured pulvelli; and at *c*, two setæ.

Fig. 7.—Alula or winglet, with its pilose membrane stretched

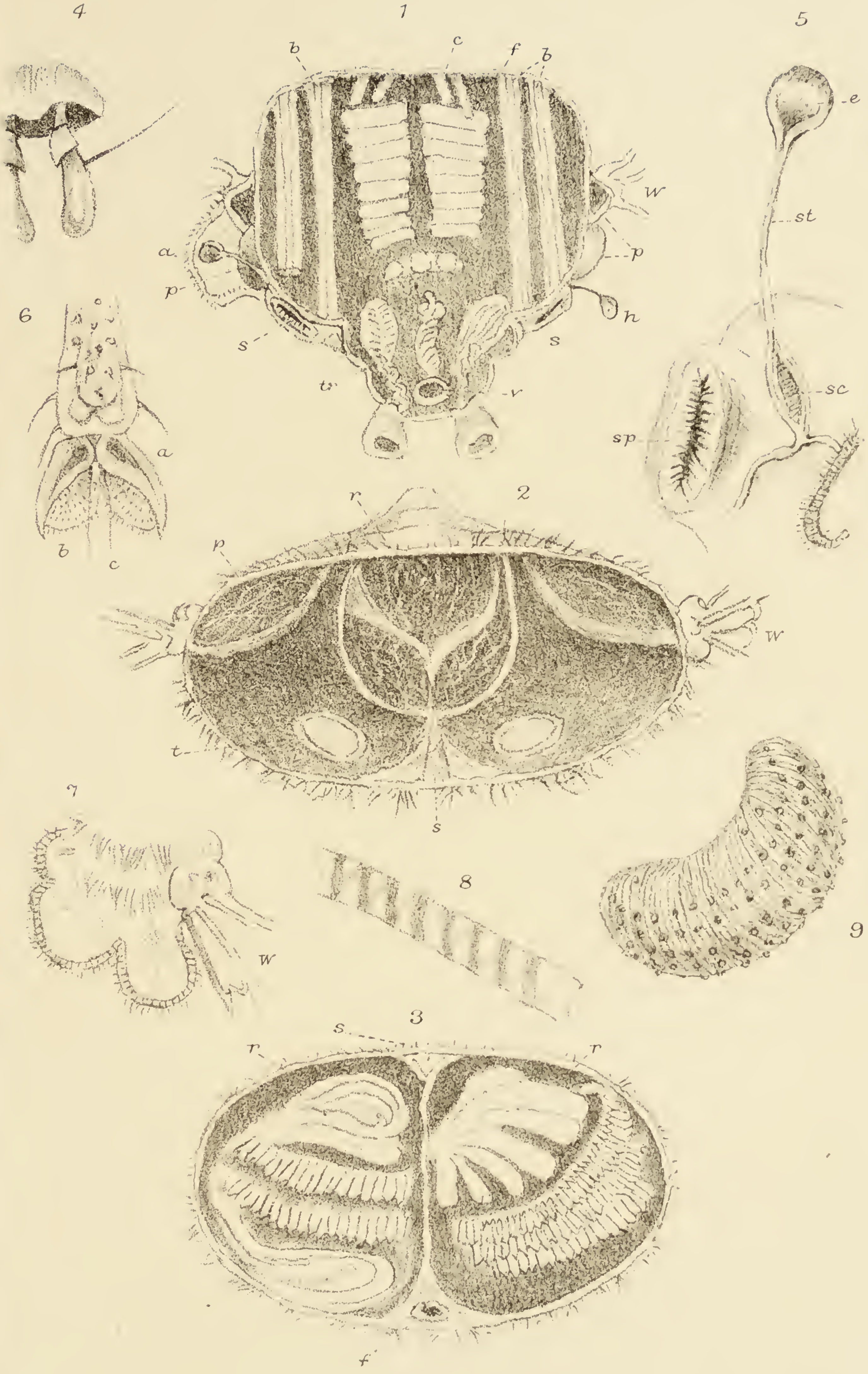
over strong chitinous striated rings, forming three unequal lobes. The cubitus and costa of the wings are seen at *w*.

Fig. 8.—Portion of one of the long convoluted tracheal vessels, which more or less crowd the upper part of the thoracic cavity. They are of large calibre, and the spiral band within is very distinct.

Amplification.—Figs. 1 to 3, eleven diam. Figs. 4 to 8, thirty diam.

Fig. 9.—One of the four air-receptacles seen in the larva of *Corethra*. The surface is covered with fine annular striæ. The functions of the tubercular bodies is alluded to in the text. The air-sacs are here figured to show their analogous uses as floating bodies, with the great tracheal trunks of the larva of *Eristalis*.

PLATE IV.



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# PLATE V.

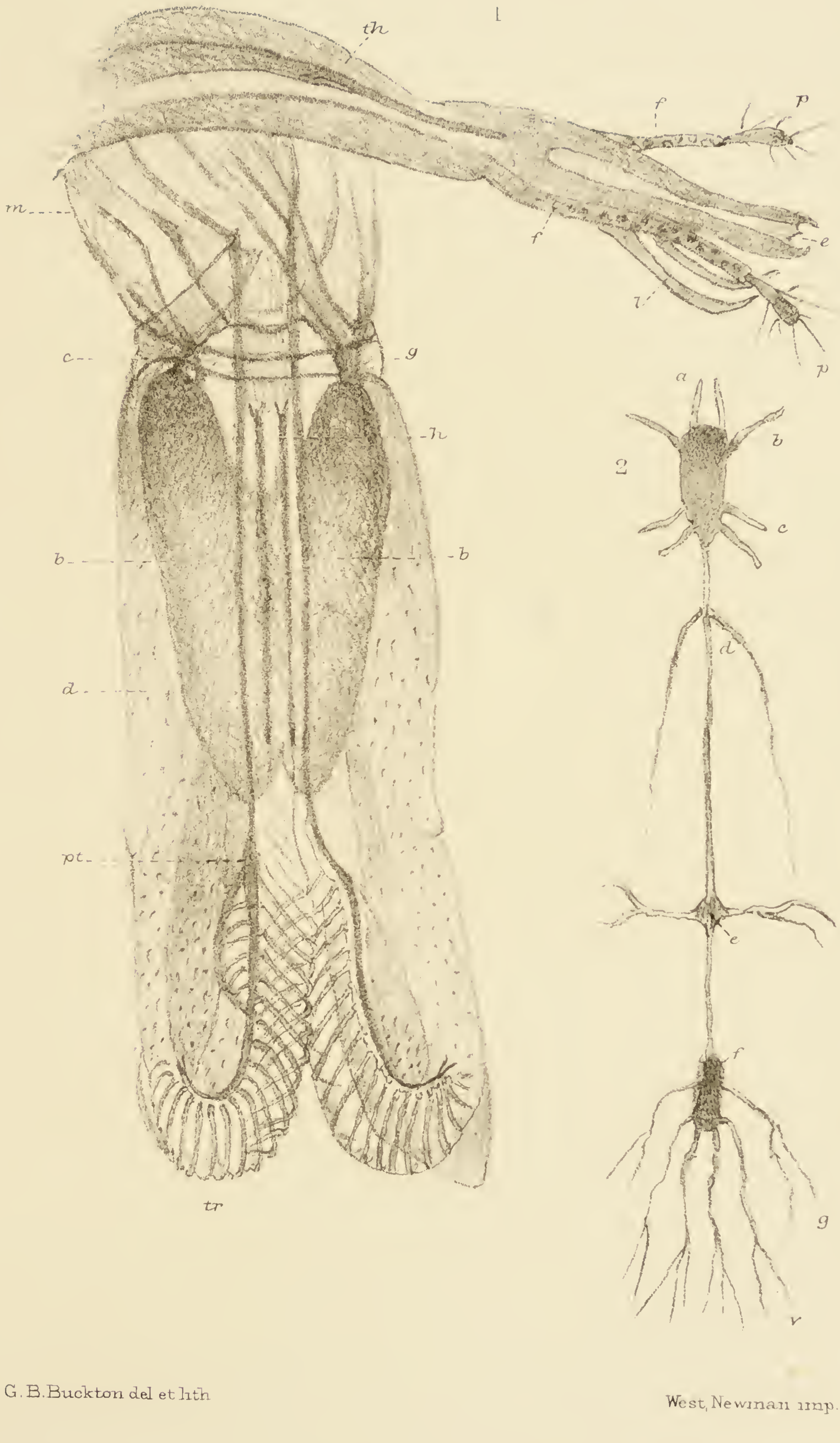
Fig. 1.—Labrum and proboscis of *Eristalis tenax*, much magnified. *th.* Grooved theca or labium, which protects the haustellum or proboscis when folded under the thorax. *f, f.* Labial palpifers, with their respective palpi at *p, p*. *e.* Grooved channel, with its notched extremity. *l, l.* Laciniæ, or cutting representatives of the mandibles. *m.* Submentum and cardo, or hinge, at *g*. *c.* Muscular bands controlling the lobes of the paraglossæ (*pt.*). *pt.* Pseudotracheæ, forming loops of the paraglossa. Together they form conspicuous pads, which act partly like a sponge, and convey liquids and pollen through the channel (*h*) to the pharynx. *a* Prelabrum. *b, b.* Lobes of the haustellum employed during the exhausting and sucking action of the pads (*tr*).

Fig. 2.—Ventral nervous system of the imago. Ganglion of the thorax. *a.* Nerve twigs leading to the cerebellum. *b, b.* Nerves running to the anterior legs. *c, c.* Nerves running to the intermediate and posterior legs. *d, d.* Abdominal nerves. *e.* First abdominal ganglion. *f.* Second abdominal ganglion. *g.* Nerves to the genitalia. *v.* Nerves supplied to the rectum and anal organs.

This drawing of the nervous system of *Eristalis* is after Burmeister.

Amplification.—Fig. 1, thirty diam.

# PLATE V.



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## PLATE VI.

Fig. 1.—Section through the eye of *Eristalis tenax.* Magnified thirty diameters. *a.* Cornea composed of very numerous lenses, ranged on an irregular curve. *r.* Retina at the base of the optic cones. *ch.* Choroid surrounding the vitreous humour. *f.* Nervous fibrils running to (*p*) the pigmental floor of the optic nerve. *g.* Cephalic ganglion.

Fig. 2.—Parts of the same insect, much more magnified. *d.* The cornea, lenses, and bristles. *y.* Crystalline cone, at the bottom of which is (*p*) the opening or pupil of the iris. *r.* The retina. *f, f.* Dark pigmental bands, which isolate the individual cones from extraneous light.

Fig. 3.—Similar parts from the eye of *Calliphora erythrocephala* drawn for comparison.

All these specimens were stained with methyline blue, and drawn by camera lucida.

Fig. 4.—Part of the cornea, showing the external forms of the lenses of the eye.

Fig. 5.—A rod and cone from the eye of *Melolontha*, after Straus Durckheim. *c.* Corneule or lens. *a.* Anterior chamber. *p.* Pupilary aperture. *ch.* Choroidal coat, surrounding the cone with (*v*) its vitreous humour.

Fig. 6.—Part of the viscera of a young larva of *Eristalis arbustorum. tr, tr.* Portions of the great dorsal tracheal trunks. *y.* A smaller tracheal vessel, branching over, and clasping the larger vessel. *ph.* The pharynx distended with food. *m, m.* Ganglionic masses. *ch.* Proventricle or chyle-stomach distended; the surface studded with dark pigment cells. *m, m.* Entrances of the malpighian glands. Below these is the commencement of a long tortuous intestine. The chyle-stomach of this specimen was charged with a quantity of opaque white milky fluid.

Fig. 7.—Part of the intestine, naturally one inch long, filled with nucleated cells, oil-globules, and this same milky fluid.

Amplification.—Fig. 1, thirty diam. Figs. 2, 3, 4, 7, forty diam. Figs. 6 and 7, eleven diam.

# PLATE VI.

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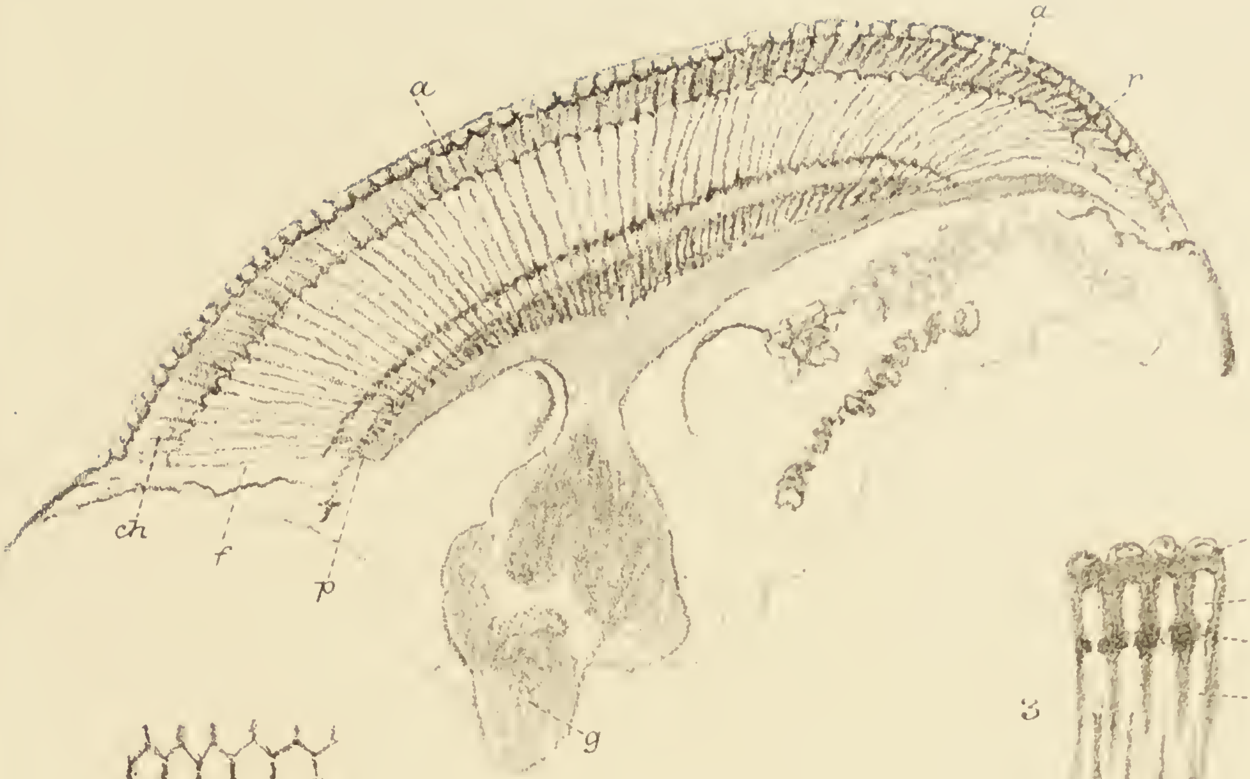

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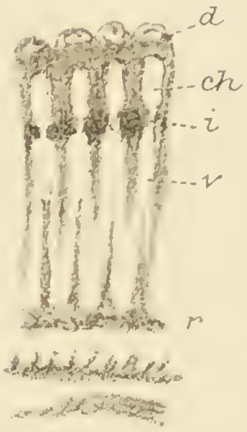

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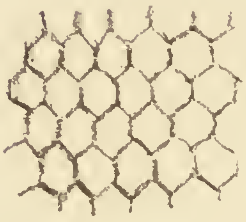

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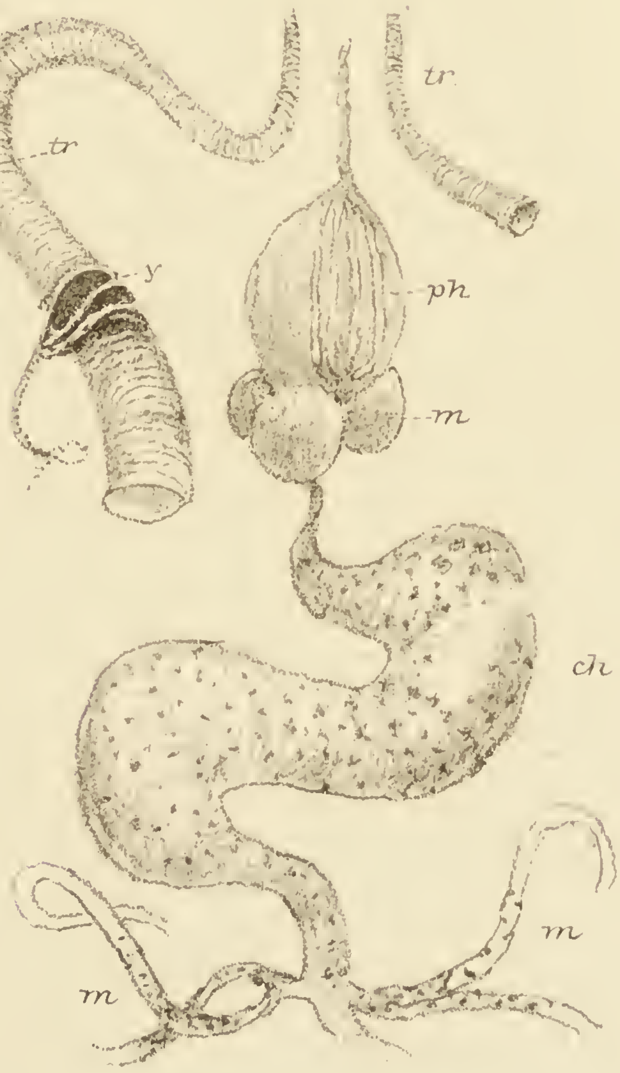

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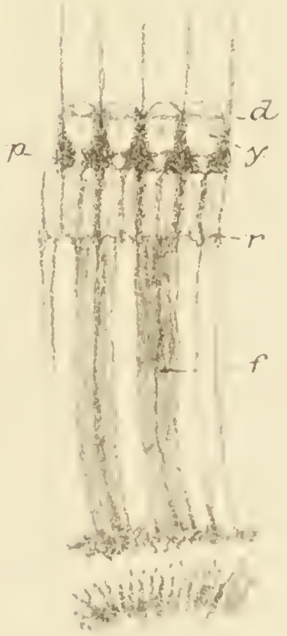

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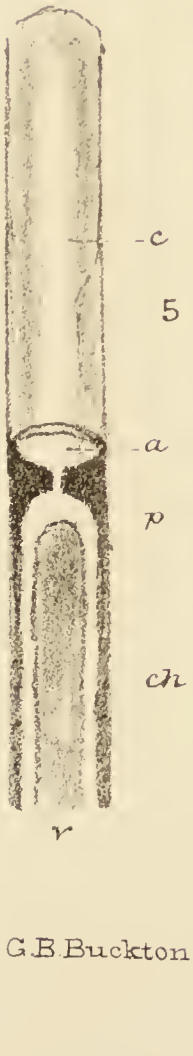

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## PLATE VII.

Fig. 1.—The nervous system of the larva of *Eristalis*, consisting of a short ventral cord without ganglia. *œ*. The portion which communicates with the œsophagial ring. *th*. Five pairs of nerves, which serve the organs of the thoracic region. *i*. A bundle of nerves, which at their terminations are distributed over the intestines.

Copied from Burmeister.

Fig. 2.—Gizzard or crushing viscus, situated in the thoracic cavity of the adult. The œsophagus at the anterior end is broadly striped, and below the insertion muscular bands cross the viscus. Below these bands several short and blind gastric glands pour in their contents. The lower exit in this example is not shown.

Fig. 3.—Sectional view of part of the abdomen and thorax of a ripe female fly. The dorsal plates have been removed to show the dense manner in which the ova are ranged in series. *th*. Thorax with wing insertions. *o*. Ova ranged in vertical rows. *v*. Ovipositor partly extruded.

Fig. 4.—Head of *Eristalis*, removed to show at *f* the three foramens through which the muscular tendons, œsophagus, and nerve-trunks pass. *h*. Haustellum. *p*. Paraglossæ or sucking pads.

The whole is viewed from the back of the head. Its concave surface slides, and easily rotates over the horny processes of the thorax.

Fig. 5.—Raised bullæ on the thorax to receive the head, as above described. *f*. Foramen which communicates with the head and the apparatus of the neck.

Fig. 6.—Two of the compound masses of thoracic muscle, much magnified. See figures in Plate IV., at *f* and *b*. The manner in which the separated fascicles are built up of rods, each with its central spot (*ms*), may be remarked. If torn asunder the fracture of these bundles is sharp, as if cut with a knife.

Fig. 7.—One of the four "renal organs" of *Syrphus luniger*, showing the elaborate manner in which the tracheæ (*tr*.) spread like the branches of a tree over the gland.

By the kindness of Mr. C. H. Vine I am allowed to reproduce, but on a smaller scale, his beautiful drawing of this singular structure. Organs having the same functions in *Eristalis* are figured in Plate VIII., *r*, of this essay.

Fig. 8.—Laminated masses or flaps, edged with broad dark-tinted bands, with striated edges, disposed like tiles on a roof. These are ranged in bundles close to the viscus, drawn on this Plate, fig. 2. The significance of these flaps, which do not appear to be sebiferous, is at present obscure.

Fig. 9.—Section made vertically through the thorax and abdomen of the adult *Eristalis tenax*, showing the large air-cavities, and some of the viscera *in situ*. Many of the internal organs are obscured by white adipose tissue, but the following details are partly delineated. *ad, ad.* Adipose or fatty oil stored in numerous sacs. *p, p.* Pulmonary chambers or air-spaces in the fly's body. *sc.* Hollow scutellum, with a fimbriated mass within. See fig. 8 of this Plate. *œ.* Œsophagus, with part of the chyle-stomach or (*ch*) proventricle. The rest is buried in fat, but it is seen to join with the rectum lower down. *i, i, i.* Parts of the large intestine cut across; finally it joins the rectal pouch at *r*. *m, m.* Traces of malpighian vessels. *tr, tr.* Passages to the trochanters of the legs. *f, f.* Muscular fascicles in the thorax. *s, m.* Division between the thorax and abdomen. There are certain fimbriated flaps within or near to the air-pouches, which possibly may in some way be connected with the respiratory system.

Figs. 1, 2, 3, 4.—Parts of the dorsal plates, seen edgeways.

Amplification.—Fig. 6, eleven diam. Fig. 8, thirty diam.

PLATE VII.

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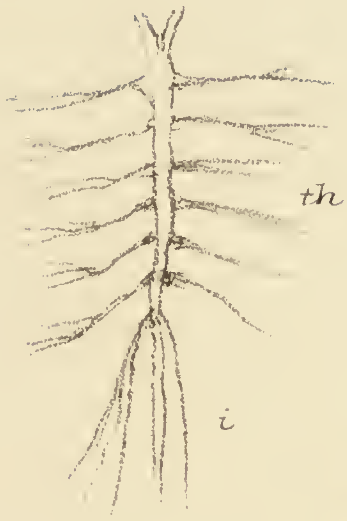

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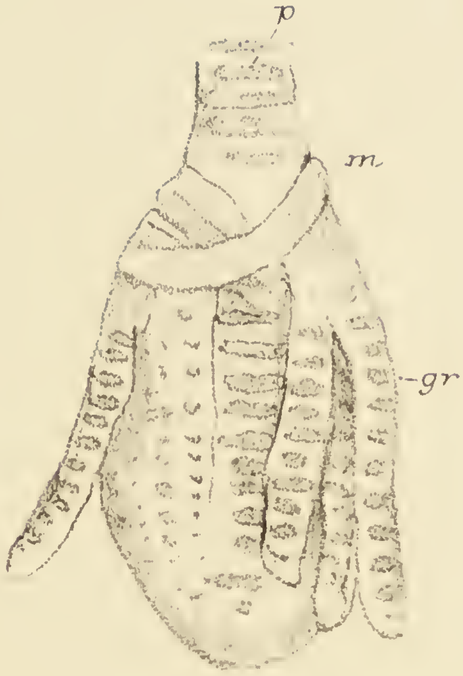

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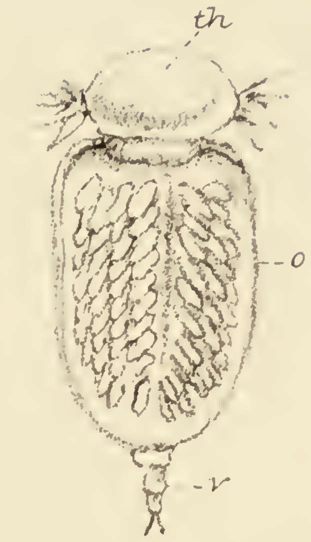

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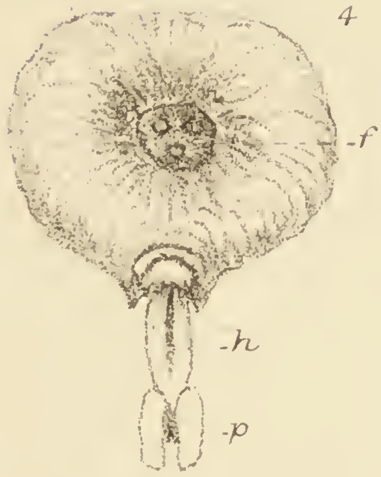

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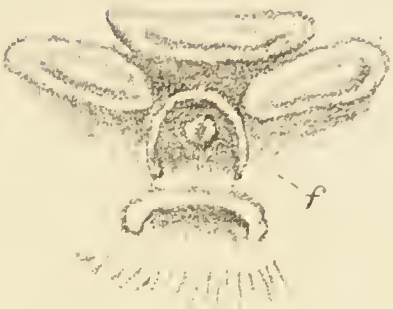

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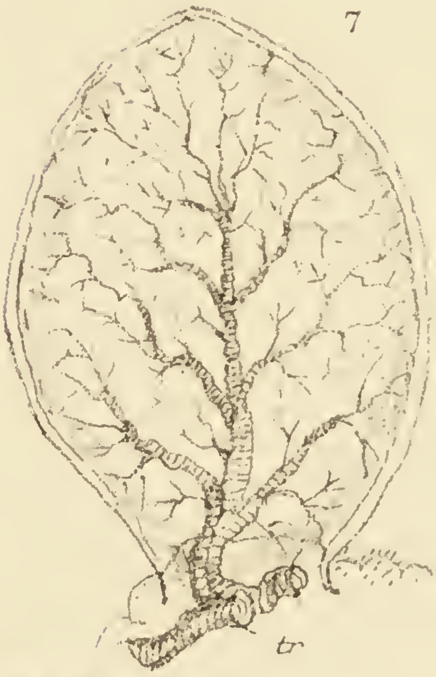

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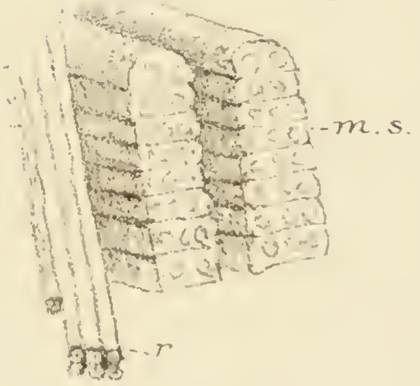

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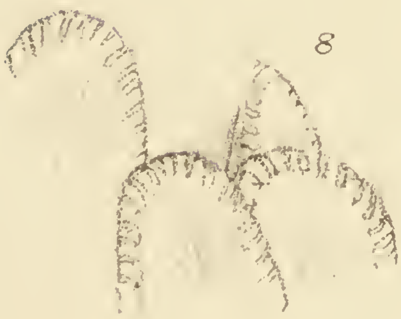

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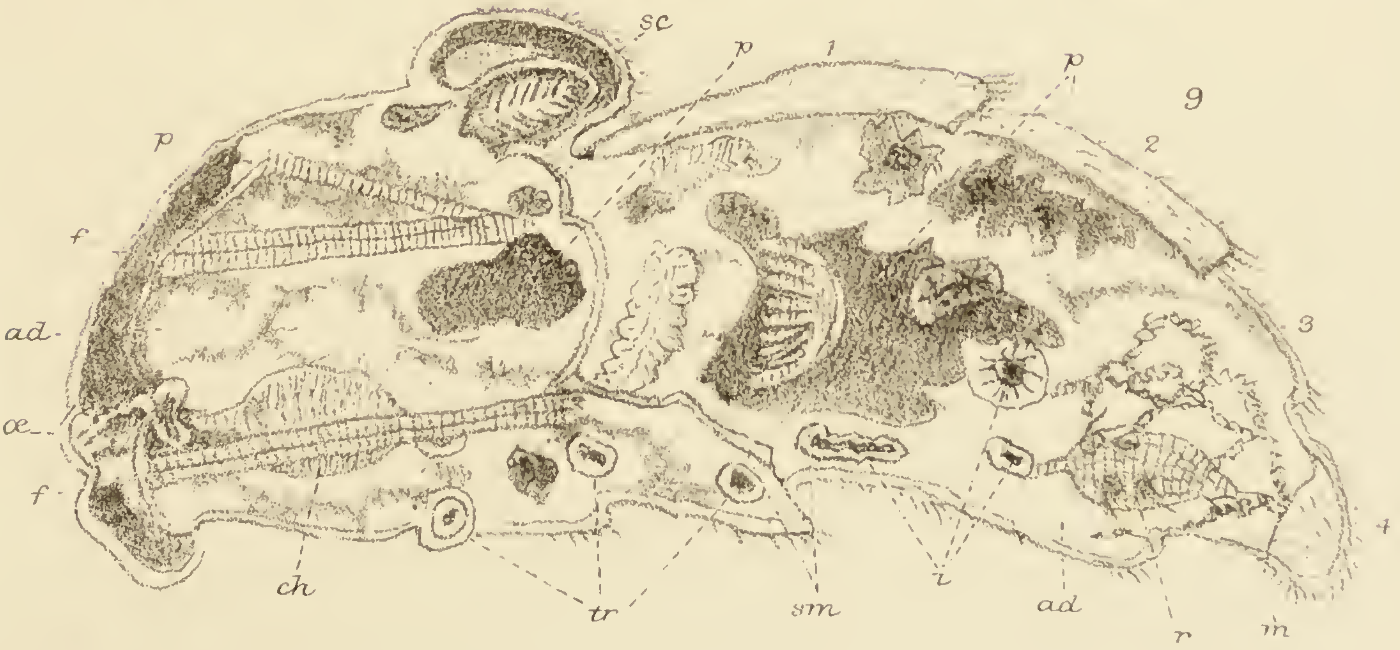

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## PLATE VIII.

Fig. 1.—Colon or rectal pouch of the male *Eristalis tenax*, showing longitudinal and transverse muscular fibres. *d.* Part of the distal intestine, with epithelial spots. *r.* The rectum, with its glands. *g, g, g, g.* The rectal glands, which protrude into, and have their free ends within, the pouch-walls. The outer portion of each gland unites with three or more tracheal vessels, which join into one larger trunk of great length. The long tube below connected with two nearly spherical glandular bodies I regard as the testes.

Fig. 2.—Camera drawing of the complete alimentary system of the male insect. *p.* Pharynx (or gizzard ?), into which the ducts enter, proceeding from the sucking stomach. *s, s.* Salivary vessels. *ch.* Chyle-stomach, nearly empty, showing its longitudinal pleats. *i.* Proximal intestine. *d.* Distal intestine, with fæces enclosed. *m, m.* Malpighian vessels running to the neighbourhood of the rectum. *r.* Rectal pouch. *t.* Testes, placed amidst many loops of long thread-like vessels.

Fig. 3.—Vertical and longitudinal section across the thorax and abdomen of the fly. *th.* Muscular bands connecting the front and hind plates of the thorax. *d, d, d.* Abdominal rings. *s.* Plicated septum dividing the cavity right and left. *f.* Fimbriated muscles projecting into the great air-pouches. *v.* Ventral plates.

Fig. 4.—The testes of *Syrphus luniger*. *v.* Vesica seminalis. Copied for comparison from a drawing by Mr. C. H. Vine.

Fig. 5.—Portion of the abdominal septum in *Eristalis tenax*, showing the cross ridges of the elastic folds.

Fig. 6.—Large branched trunk of the imago, showing an abdominal stoma at the intersection, and the air chamber in communication therewith.

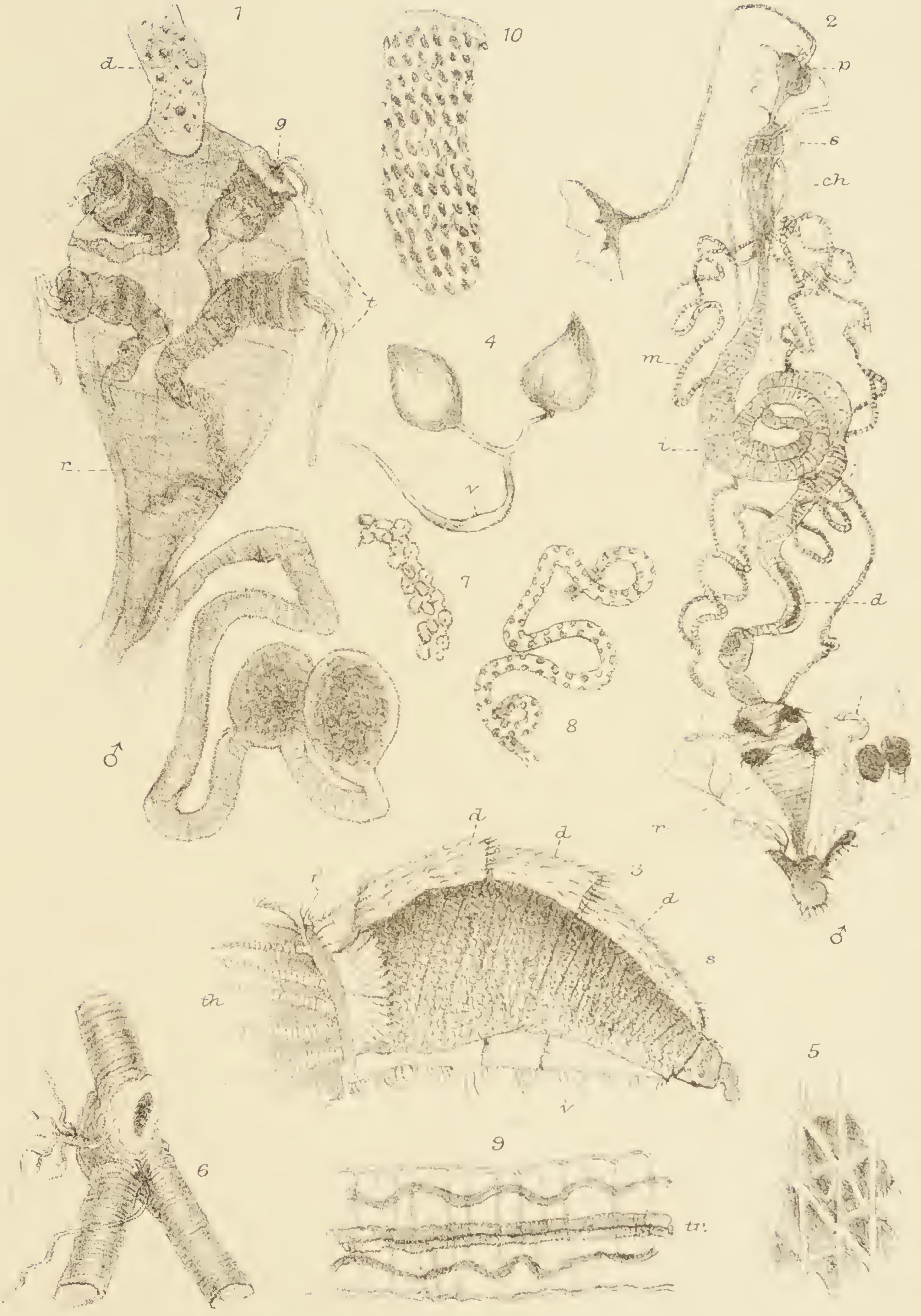
Figs. 7 and 8.—Portions of the Malpighian tubes, with their glandular walls.

Fig. 9.—Part of the caudal respiratory tube of the larva of *Eristalis tenax*, showing the two parallel central tracheæ, and the two elastic bands which cause the retractation of the organ as noted by Viallanes. See page 65.

Fig. 10.—The ova of a gnat (*Chironomus*) disposed round the surface of a cylindrical mass of mucilage, and described on page 18 of this essay.

Amplification, 1 to 5, thirty diam.; 2 to 9, eleven diam,

PLATE VIII.



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# PLATE IX.

Fig. 1.—Ovipositor of *Eristalis tenax*, showing at 5, 6, 7, 8, its jointed character, the papillæ, and anus. *a.* Anus. *o.* Membranous ovarian duct.

Fig. 2.—Bunch of ovarian capsules, taken from a female in the month of April. *st.* Stroma.

Fig. 3.—Alimentary and part of the reproductive organs of the female *Eristalis tenax*. *g.* Gizzard. *s, s.* Salivary organs. *c.* Sucking stomach, with its duct leading to the gizzard. *ch.* Proventricle, with its muscular folds. *m, m.* Malpighian vessels, inserted just above the proximate intestine, *p.* *d.* Distal intestine, leading to the rectal pouch. *r.* Rectal organ, with its four glands. *o, o.* Bundles of ova in their follicles, not fully developed? *od.* Oviduct, uniting with other ducts below. *sp.* Spermathecæ, with their ducts, at the entrance of the vagina. *v.* Part of the "vaginal ovipositor" retracted. *sb.* Sebiferous glands in loops. *a.* Anal opening and scales. All drawings made with the camera.

Fig. 4.—Hard capsules surrounded with a transparent membranous coat, and apparently in connection with the malpighian tube.

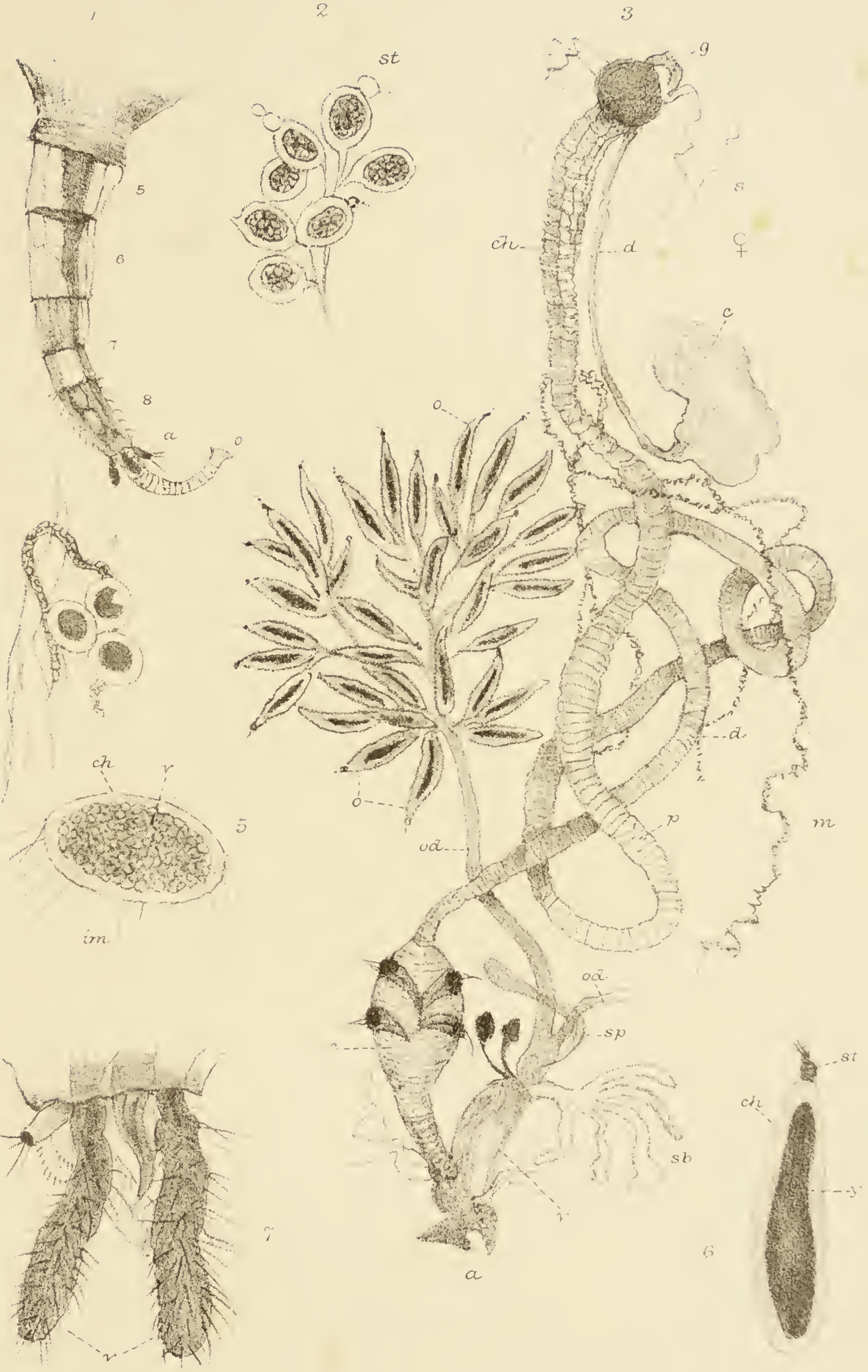
Fig. 5.—Fecundated ovum which has commenced its segmentation. *v.* The yolk. *ch.* The chorion. *im.* Part of the investing membrane.

Fig. 6.—Ovum, with its chorion and the stroma, showing germs of future eggs. Taken from one of the follicles represented at *o*, fig. 3.

Fig. 7.—Apex of the abdomen of the female *Eristalis*, the ovipositor being retracted within the body. *v, v.* Anal scales or palps. *a.* Anal opening at the end of the retracted ovipositor.

Amplification, 1, 3, 4, eleven diam.; 2, 5, 6, 7, thirty diam.

PLATE IX.



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